Control ENGINEERING

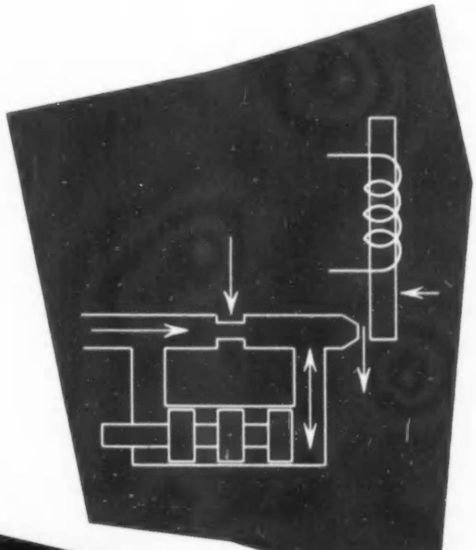
INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

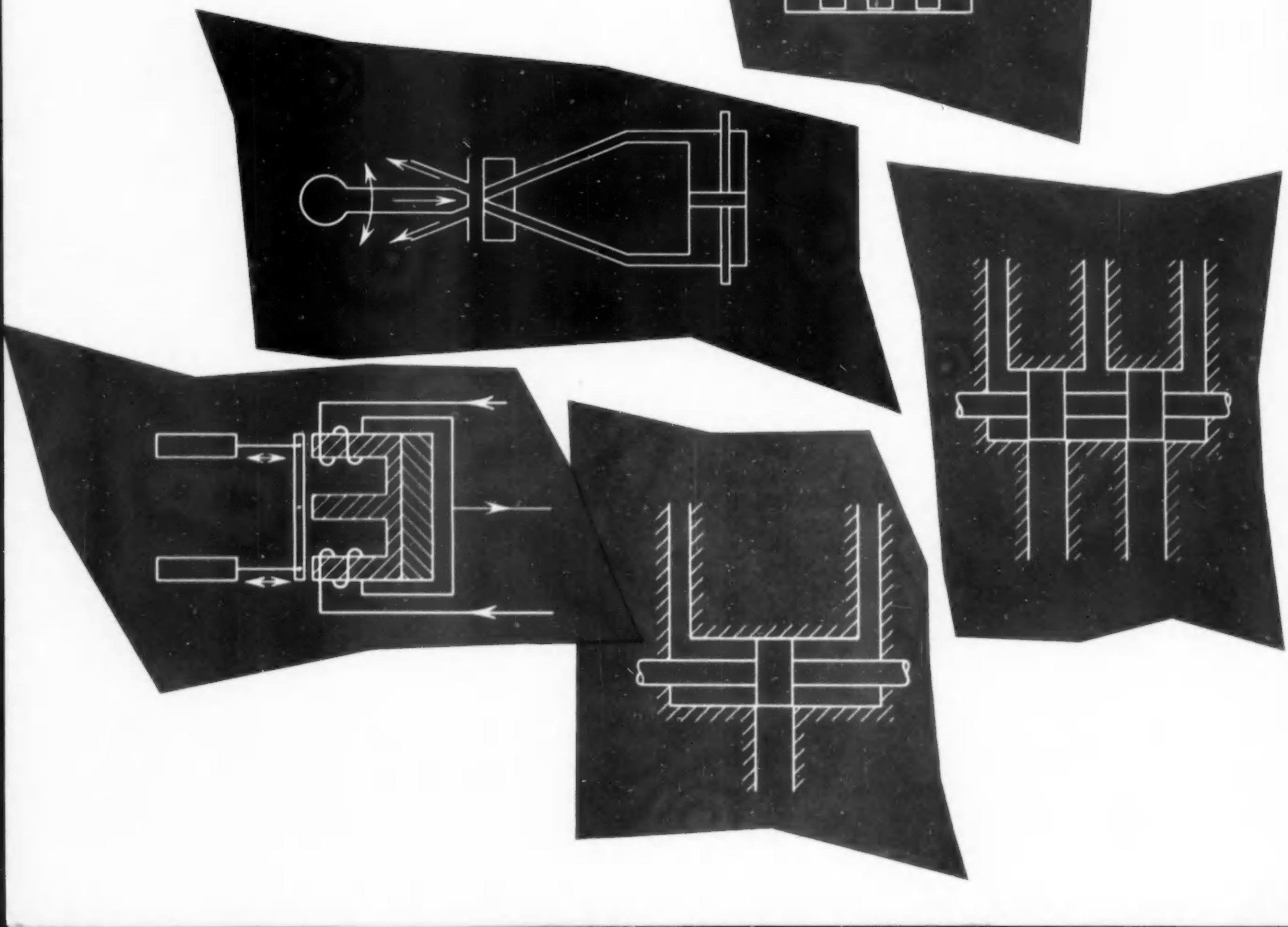
A McGRAW-HILL PUBLICATION

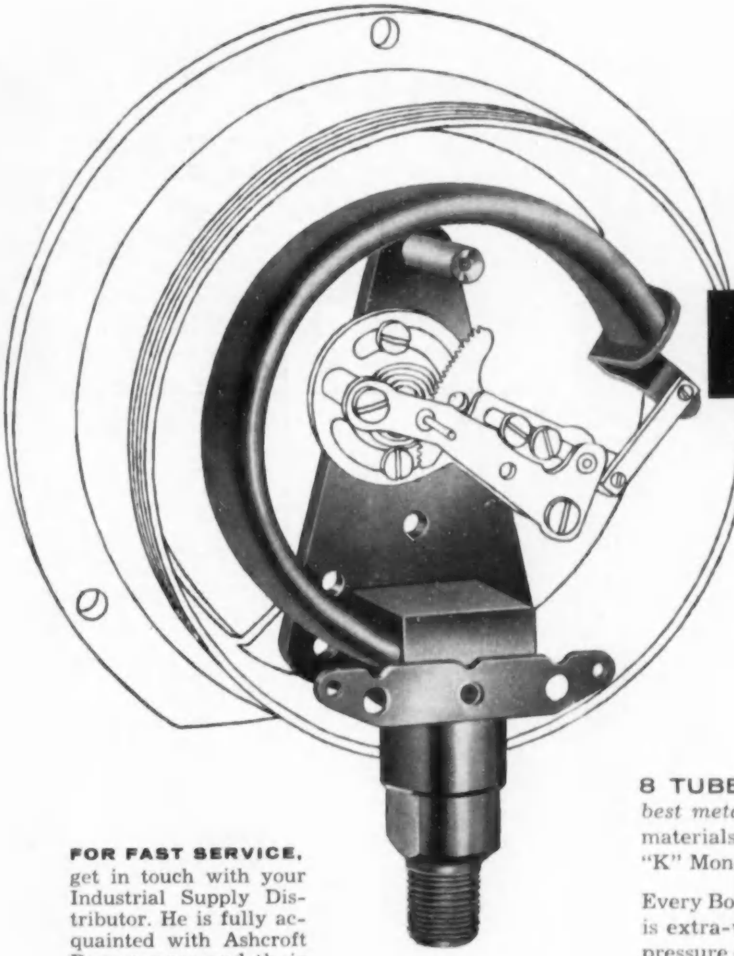
PRICE 50 CENTS

JUNE 1956

A Functional Survey in 12 Pages of Electrohydraulic SERVO VALVES







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8 TUBE MATERIALS permit selection of the *best metal* for particular service conditions. These materials include phosphor bronze, alloy steels, "K" Monel, stainless steels, and beryllium copper.

Every Bourdon tube used in the Ashcroft Duragauge is extra-wide – highly sensitive to slight pressure changes. Socket and tip joints are welded or brazed, then stress relieved after assembly, to assure maximum safety and uniform structure for highest corrosion resistance and strength. Each tube assembly is "whip tested" at pulsating pressures approximately 50% higher than its pressure rating to insure calibration stability.

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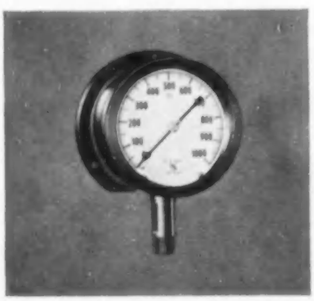

1850 ASHCROFT U.S.A.

In Canada: *Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario*

ASHCROFT GAUGES

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONNECTICUT

MAKERS OF 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN-MICROSEN' INDUSTRIAL ELECTRONIC INSTRUMENTS, *Stratford, Conn.* 'HANCOCK' VALVES, *Watertown, Mass.* 'CONSOLIDATED' SAFETY RELIEF VALVES, *Tulsa, Oklahoma.* AIRCRAFT CONTROL PRODUCTS, *Danbury & Stratford, Conn. and Inglewood, Calif.* "SHAW-BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES, *Muskegon, Mich.*

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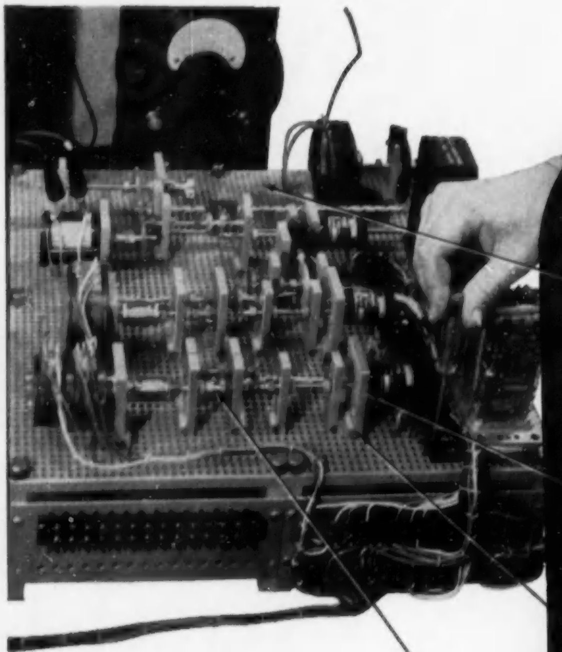
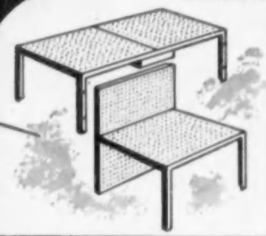


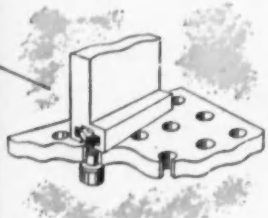
EXCLUSIVE ADVANTAGES OFFERED BY SERVOMECHANISMS

1



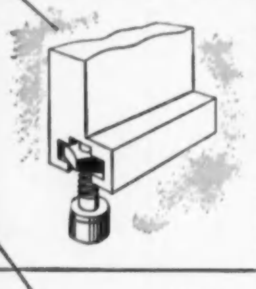
Foundation Boards, with drilled holes, can be combined in vertical and horizontal planes and because the boards are cut from rolled stock, stress-relieved and ground flat, they will not warp.

2



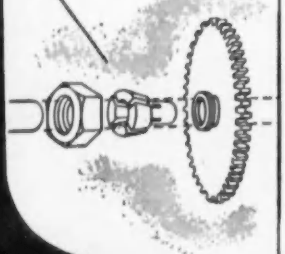
Mounting Blocks can be rotated and moved in any part of 360°. Captive nuts are free to travel the length of the base slot. This permits the blocks to be adjusted in a lateral direction.

3



No worn thread trouble. Steel captive nuts in mounting blocks are inherently reliable, and can be replaced if damaged.

4



Gears are attached to shafts with tapered collets which fit securely into integral tapered hubs. Guaranteed true balance and concentricity.

EXCLUSIVE ADVANTAGES...

Servomechanisms' Mechanical Development Apparatus—an assortment of precision-built, mechanical components such as mounting blocks, shafts, gears, cams and couplings—offers exclusive advantages not found in similar equipment. MDA is ideally suited for use in prototype and small quantity production equipment where valuable design and procurement time can be saved by using Servomechanisms' off-the-shelf equipment.

And, *in the lab*, MDA is widely used to simulate instrument and control systems in the breadboard phase. At the completion of a breadboard evaluation, this equipment can quickly be disassembled and reused in other laboratory projects.

The immediate delivery of these versatile precision-built components, plus the exclusive advantages listed, combine to make this equipment extremely economical, practical and easy to use.

SERVOMECHANISMS INC.
PACKAGED FUNCTIONAL COMPONENTS

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625 Main Street, Westbury, L. I., New York

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EA256

Control ENGINEERING

JUNE 1956

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

FEATURE ARTICLES

IDEAS AT WORK

DEPARTMENTS

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SHOPTALK

MORE FEEDBACK FROM EUROPE

Last April's *Industry's Pulse*, the work of Netherlambulating Mel Fusfeld, was an example of the kind of reports we have been promising on overseas control technology. This month we go to Athens (*Control Personality*, page 13). Our reporter is Prof. John A. Hrones, director of the Dynamic Analysis & Control Laboratory at MIT. John, who is on a four-month junket through Europe, arrived in Athens on Feb. 20. His sketch of Nick Theophanopoulos shows he's already living up to his promise to send us reflections "on what he can see of the state of the art". Next month we will publish a Hrones' eye-view of Italian industry and the Milan Conference on Automation. Meanwhile, Mel is also on the move: we plan a discerning *Pulse*, originated by him, on the emergence of Russian control engineering.

ACTIVATED AUTHORS

Associate Editor Harry Karp, just back from a three-week swing through the West, carried tidings to gladden an editor's heart: "What with the scramble for engineers to staff the many new plants, it appears that companies are encouraging 'professional recognition' to hold their men. One important facet of this seems to be published articles. Convair in San Diego, for example, not only makes it company policy to persuade its men to write—but will pay them for articles published (if the magazine is a nonpayer)." Harry's full briefcase proved these companies mean business.

WELCOME JACK JOHNSTON

When Marion Long, a Consulting Editor since our first issue, found he was moving around too much to keep in touch with us, he suggested we put someone else in his spot. As our masthead shows, our luck is holding—now we have du Pont's Jack Johnston (CtE, April '55, p. 11) to prod us and keep us abreast of the process field. Thanks much, Marion, for your fine help. Welcome aboard, Jack.

Our Consultants *do* get around. Last month in Shoptalk we told how Groucho encountered Grabbe. Here's the proof. The man with the high forehead is Gene. On the left is his comely quiz partner.

FEEDBACK

Time, tide, and computers . . .

The editors of this magazine control the processing of ideas from authors through the printing press to the reader. We plan articles (establish set-points), hold authors to deadlines (process dead-time), reshape and organize their manuscripts (data reduction), and send out material to the printer on the one day of the month that he prints the magazine (on-the-fly synchronization with the "muscles" of our process).

Normally, developments and innovations in the products used in our field do not move so rapidly that they outstrip our time-consuming process. But small-scale computers are an exception. Our readers report that the article "Small-Scale Computers as Scientific Calculators", by John W. Carr III and A. J. Perlis, published in our March, '56 issue, is an excellent and useful roundup of information, accurate up to the time that the authors dropped their pencils. But between the time that they made their last literature check and the time that we mailed the issue, computer innovations went on apace and new literature issued. To bring the article more completely up-to-date (April 24), we print here new information received from manufacturers since the article was published. It is clear that we could run a column of such information every month. But the better procedure is to invite Carr and Perlis to take a new slice at the end of this year and author a repeat article that will include all improvements since their first article.

Bits on Logistics Research's Alwac:

Purchase price: $48,000
Monthly rental: $1,775 (4,096 drum)
$2,050 (8,192 drum)
Words of internal storage: 8,192
One address in instruction
Operations per sec:
Normal mode: 13
With optimum programming: 38
Photoelectric reader: 400 digits per sec.
The manufacturer states that Alwac:

1) can modify location of previously written instruction addresses without extensive programming.
2) has subroutine operation as a standard operating feature.
3) has optional magnetic tape storage units with:
   256,000 words per tape
   $10,000 tape unit cost
   10,000 characters per sec reading or writing speed
   144 sec average tape search time control for 16 tape units, max
4) uses the rapid-access loop technique
5) has an optional 400-digit-per-sec input reader

THE PROBLEM FORUM . . .

. . . is on the road again. We are certain that many of our readers can solve the technological problem posed, but who can meet the economic challenge? Take a crack at it. We'll pay for unique solutions and we'll continue honorariums for problems that we publish.

NEEDED: a 5,000-point temperature-alarm system that monitors in 50 groups of 100 each. All within any group have the same pre-set temperature of between 85 and 105 deg C. The specified accuracy is within plus or minus 2 deg. C. Required: only low-temperature alarm; automatic shutdown is unnecessary. Once per hour per position scanning is satisfactory.

APPLICATION: monitor surface temperature of 5,000 brass concentric-tube heat exchangers 24 in. long and one in. in diam. Distance between control panel and measuring points: max, 500 ft; average, 50 ft. As the measuring area is often contaminated with explosive vapors, the energy limit of ac circuits is 200 ergs per cycle.

Adjustment of alarm temperature for each group of 100 points from a central location is a desirable feature, but to minimize cost, manual setting of each point is acceptable.

The savings will be from: 1) reduced labor costs, as operators now make all readings with portable pyrometers; 2) isolation of faulty product before it leaves the department for subsequent manufacturing.

Allowable total installed cost: $10 to $15 per point; $30 per point definitely prohibitive—and just that is the problem.

6) programming characteristics given in Table III, page 103, should read:

A B C D E F G H
• 0 • • • • 0 0

Bits on Bendix G-15:

New brochure No. 2-4 and manufacturer's letter indicate:

1) average access time for main memory: 14½ millisec.
2) average access time to 16-word rapid-access memory: 0.54 millisec.
3) magnetic tape units, with storage of up to 300,000 words, read or write at 7½ in. per sec; average scan six times as fast. Maximum of four tape units attachable.
4) punched-card input-output equipment at speeds of 17 and 11 characters per sec, respectively, are available.
5) optional digital differential analyzer has a capacity of 108 integrators, or 108 constant-multipliers with a speed of 34 iterations per sec.

Bits on Burroughs Corp.'s E-101

1) Has either a 100- or 220-word memory for numbers.
2) Orders can be supplemented by instructions from a paper-tape loop read at 20 characters per sec.
3) Output ganged printer prints up to 24 digits per sec and direct keyboard input enters "trailing zeros" automatically.
4) Has a "return jump" feature from subroutines.

Finis until the next annual roundup. Ed.

Notching motor catches the eye

To the Editor—

We are at the present time involved in the development of new digital techniques and very much appreciate the article "Flight Control and the Digital Computer", published in your October, '55 issue.

The notching motor (mentioned in the article) is particularly interesting to us. Are such motors shelf items? Is it possible to obtain them? If so, where? What is the smallest physical size of such a motor?

Frank P. Tomaiuolo
The Newton Company
Manchester, Conn.

. . . and author answers

The bi-directional notching motor used in the project was designed under another classified contract at Hughes Aircraft Co. and only two models were built. Recently several

FEEDBACK

such devices have appeared on the market. Some of the manufacturers are:

Sigma Instruments, Inc., South Braintree, Boston 85, Mass.

Sterling Engineering Co., Princeton, Ind.

Stepping Motors, Culver City, Calif.

Nemeth, Inc., 2223 S. Carmelina Ave., Los Angeles 64, Calif.

E. M. Grabbe

Slubbers passed wrong

To the Editor—

As the manufacturers of the "Autocount" wool carding control equipment, we were very interested to read the review of this equipment on pages 105 and 107 of the February 1956 edition of Control Engineering.

We should like to draw your attention to the last sentence of the paragraph at the top of page 107. This sentence refers to the fact that the slubbers are rubbed into the tubes in preparation for the weaving process, but we would draw your attention to the fact that the slubbings are passed to the spinning frames as the next part of the process.

C. J. Teece
Lancashire Dynamo Electronic Products, Ltd.
Rugely, Staffordshire, England

Seeks literary nostrum

To the Editor—

In your article in the April 1956 issue, page 19, you indicate that Mr. Ziebolz has published a paper on the subject of patents. I should appreciate your citing the publication in which this article appeared. Or, if it was an independent publication, where may I obtain a copy.

I. Jordan Kunik
New York City

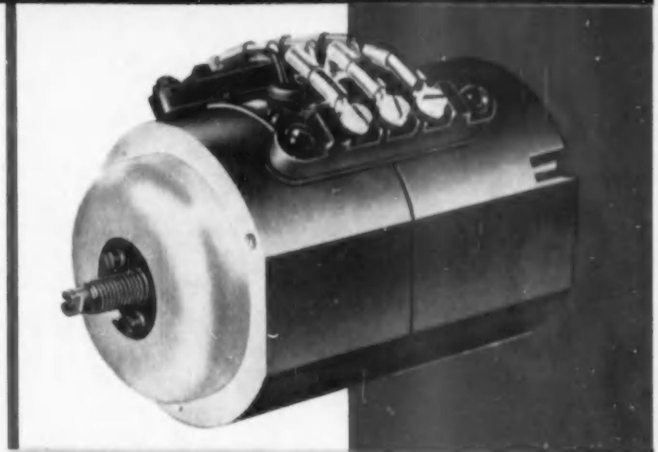
Mr. Ziebolz has written two volumes under the title, "Analysis and Design of Translator Chains". The first volume contains text, the second, diagrams. Both volumes were published by Askania Regulator Co., Chicago, Ill. Ed.

Editor's debris finds a home

To the Editor—

The editor of *Shoptalk*, April '56 issue, mentioned a Nylon-insulated thermocouple among the collection of "debris" cluttering his desk. I would

now ready for many jobs...

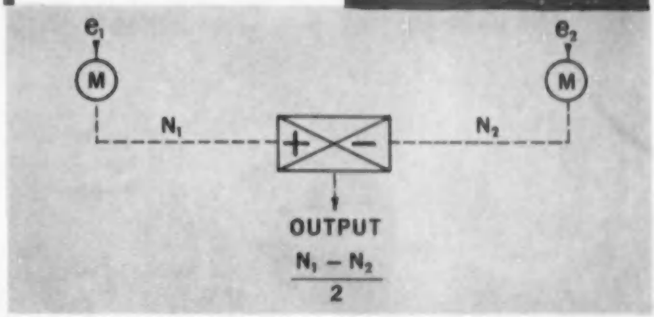


KOLLSMAN synchronous differential

... in production

- compact—only 2⅜ x 4¼ inches.
- lightweight — 28 ounces.
- inherently accurate — driven by synchronous motors
- for many 60 cycle and 400 cycle applications
- operates from single or polyphase sources
- maximum torque — 1.0 oz./in.

Kollsman's control engineering specialists are ready to work with you on your specific application. Write for information today and tell us your needs.



in one package—a half-speed synchroscope with High Sensitivity plus $\boxed{\textit{usable torque}}$

This versatile half-speed synchroscope mates two tiny hysteresis-type synchronous motors of variable frequency, with an unusually efficient differential gearing system—all in one compact unit. The output shaft rotates at a speed equivalent to ½ the difference between the speeds of the two synchronous motors.

Thoroughly tested and perfected for military use, the Kollsman precision SYNCHRONOUS DIFFERENTIAL is now available for a wide range of commercial applications in speed and position control, flow control in process industries, and computer applications — to suggest but a few.

CAREER OPPORTUNITIES: *We have openings for mechanical and electro-mechanical engineers and senior technicians. Write us if interested.*

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KOLLSMAN PRODUCES: Flight Instruments • Precision Computers and Components • Engine Instruments • Optical Systems and Components • Navigation Instruments • Precision Flight Controls • Motors and Synchros • Precision Test Instruments for Aviation and Industrial Laboratories

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Servo motor-generators
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FEEDBACK

appreciate information on this, or referral to the manufacturer for product information.

Alvin B. Kaufman
Arnoux Corp.
Los Angeles

The Nylon-insulated thermocouple is manufactured by the Revere Corp. of America, Wallingford, Conn. Ed.

Errata, addenda from author

To the Editor—

In giving the April article on selecting power control valves a quick once-over, I came across a fundamental error in the discussion of the pneumatic system. On page 76 about half-way down the right-hand column there is a sentence which starts, "The value of k_1 is $k_1 2C_d w\sqrt{P_s}/p$ . . ." Obviously this equation is for flow of hydraulic fluid through an orifice and not the form of an equation that expresses the flow of gas through an orifice. In looking back through my original manuscript I find that I did not show where I had gotten k_1 for the pneumatic case. I simply said, "When the desired value of $k_1 k_a k_f$ is used, the steady state load sensitivity is found to be . . ."

It looks as if the simplest way to correct the article is to say under pneumatic operation that $k_1 = (RT_s/gP_1) . \partial W_a/\partial X$, where $\partial W_a/\partial X$ was found from the measured flow characteristics given in the previous article (March, '56 issue).

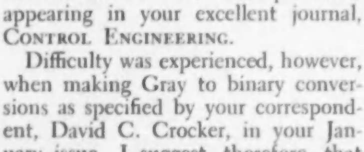
J. Lowen Shearer
MIT, Cambridge, Mass.

Everybody's showing it

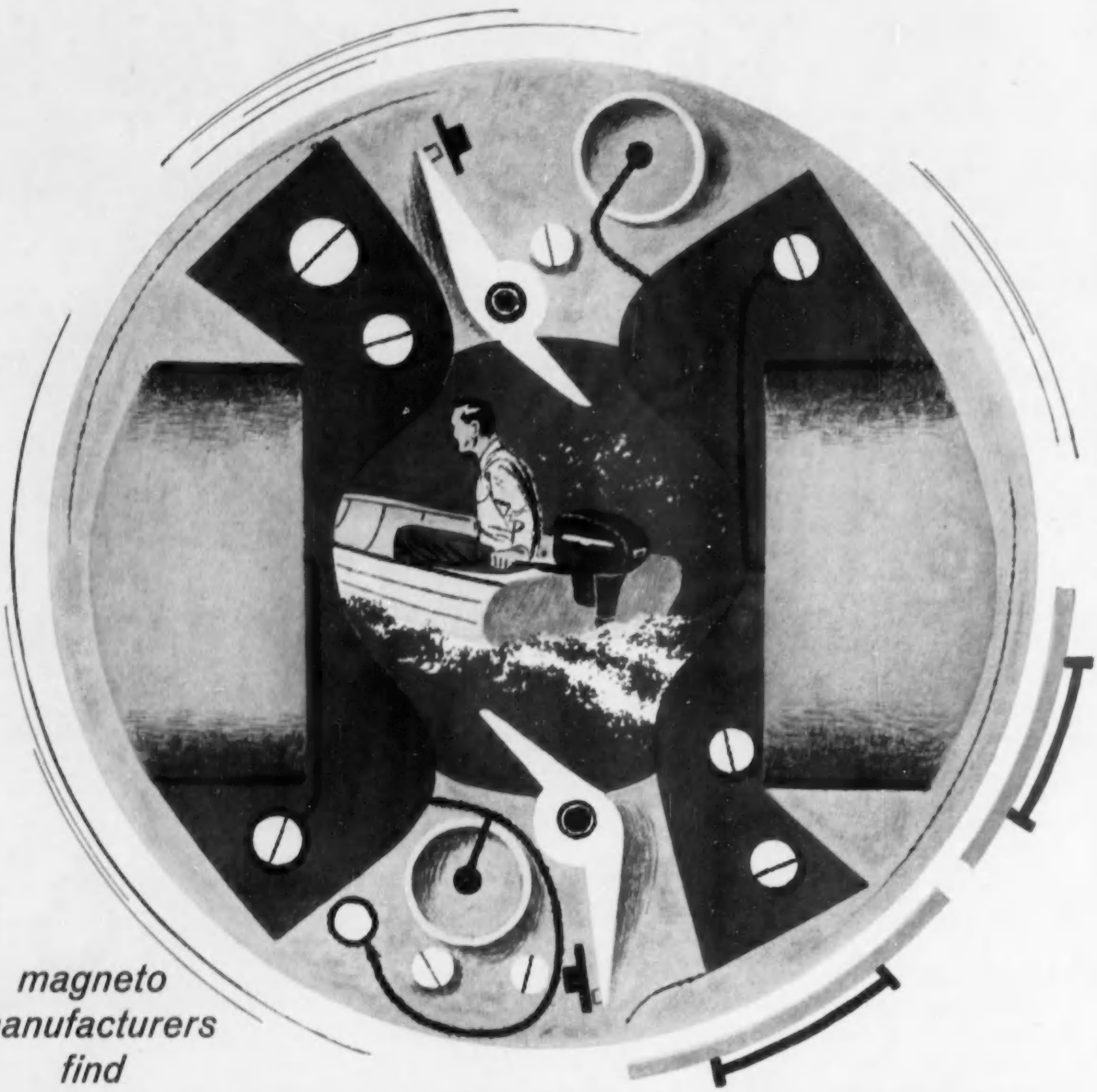
To the Editor—

I have been extremely interested in the articles and correspondence appearing in your excellent journal, Control Engineering.

Difficulty was experienced, however, when making Gray to binary conversions as specified by your correspondent, David C. Crocker, in your January issue. I suggest, therefore, that a better method of illustrating the conversion procedure would be:



E. N. Leney
Liverpool, England



NICK THEOPHANOPOULOS brings control to Athens

While there is no formal instruction offered in automatic control at Athens' National Technical University, you can be sure that many of its young graduates have been well "proselyted"—thanks to the zeal and enthusiasm of one Prof. Nicholas Theophanopoulos.

Nick built up his fervor for control while a Fulbright scholar at MIT in 1951-2. John Hrones' Machine Design Div. and Dynamic Analysis & Control Laboratory offered the right environment. But it was a project of his own that really proved the clincher: the development of a special-purpose position servo (and all the fascinating lore of control engineering that goes with such a project). When he returned to Greece three years ago to a full professorship in Mechanical Engineering at NTU, it was as a firm crusader for control.

Theophanopoulos was born in Athens in 1914 and graduated from the National Technical University—then known as Athens Polytechnic School—in 1935. From 1935-1938 he worked in Piraeus, Greece, designing small steam boilers and pumps. During '38-'40 he carried on graduate work at the Technicshe Hochschule in Berlin, where he received the degree of Doctor-Ingeneur. He served as a lieutenant in the Greek Army in the Greek-Italian war (1940-41) and at its conclusion put in three more years doing design work in Piraeus.

In 1945 Nick returned to the National Technical University, and in 1947 was elected a professor. When the guerrilla warfare period (1947-49) overtook Greece, he returned to the army—this time as an engineer in the ordnance department. He rejoined NTU for two years before heading across seas for his two-year stint in Cambridge, Mass.

He "sets the stage"

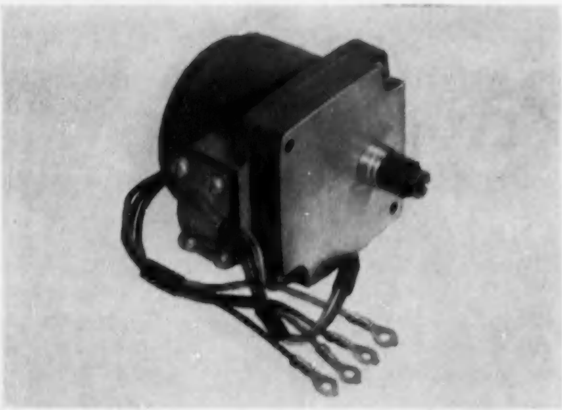
At the National Technical University Professor Theophanopoulos is in charge of machine design instruction and advanced work in dynamics. NTU's educational program, consisting of a five-year course in combined electrical-mechanical engineering, is an excellent one, and all students enrolled in it have very strong mathematical training. As Nick puts it, "The stage is set. For while we as yet have no official subject called control engineering, there exists a good fundamental training to establish such courses."

Nick is optimistic about the future of control technology in his country. He says that automatic control systems, while largely designed and built in Germany, England, and the U. S. A., are coming into wide usage in Greece. He indicates four strong areas where these systems are at work: in the modern hydroelectric plants that were placed in operation in '52-'54; in the thermoelectric plants of Piraeus and Aliveri; in the Chemical Products Co.—particularly its glass section—and in the paper industries. He also points to the rapid growth of air conditioning in Greece and the attendant control systems that are required. However, Theophanopoulos sees a critical need arising along with this growth. "We need," he says, "people adequately trained to (1) critically judge the appropriateness of the system offered for sale in specific applications, and (2) technicians to supervise the installation and adjustment of the control equipment. Getting down to cases, there is real need for mechanical engineers with training in automatic control, but our Technical University still doesn't offer any such course."

Dr. Theophanopoulos, who is in the vanguard of control engineering in his native Greece, has conspicuously set the stage for its study at Athens' National Technical University.

We suspect that Nick's lament will be answered soon—and by the man who made it.

This month's Control Personality was forwarded to us from Europe by Dr. John A. Hrones, who is presently on a tour that includes pleasant stopovers with many other former Fulbright colleagues.



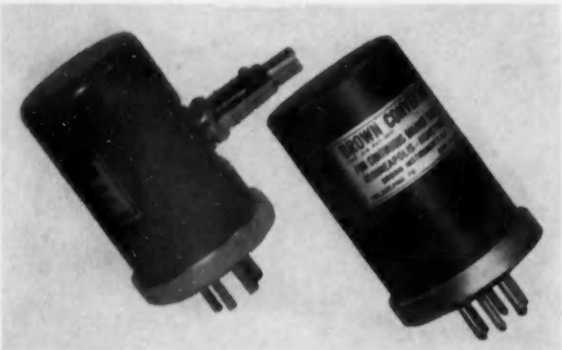
Two-phase reversible motors

Ideal for use in servomechanisms, computers, null circuits. High torque. Fully enclosed. Self-lubricating. Many variations in pinion, shaft, lead wires, and construction materials available for special requirements.

Specifications

No-load speed—rpm	27	54	162	333	1620
Rated torque—in.oz.	30	15	5	4	5
Max. torque—in.oz.	85	43	19	11	9
rpm for max. power	15	31	92	190	900

Reference data: Instrumentation Data Sheet 10.20-2.
Prices from $42.00 (lower on quantity orders).



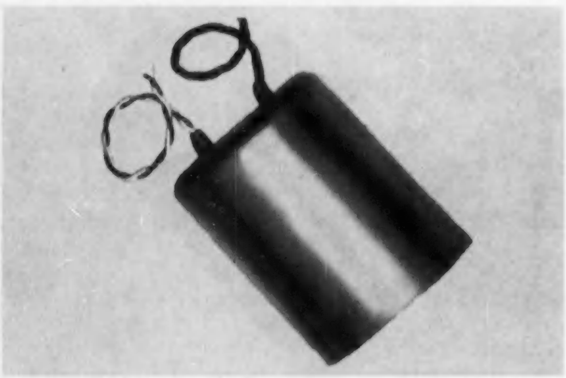
Converters

Convert d-c signals as small as 10^{-8} volt to a-c. SPDT switching action. Sensitive, stable performance . . . ideal for computers, servomechanisms, balancing circuits. Numerous special features can be provided for special needs.

Available in these ratings

Nominal frequency, cps	25	40	60	400
Synchronous range, cps	23-28	36-44	45-66	360-440
Driving coil power	6.3 volts, 60 ma			18 volts, 94 ma.

Reference data: Instrumentation Data Sheets 10.20-1 and 10.20-5.
Prices from $36.00 (even more favorable for quantity purchases).



Input transformers

Handle low-frequency a-c, or chopper-modulated d-c signals from .0005 to 200 millivolts, such as are generated by thermocouples or other transducers. Designed with highly efficient shielding.

Choose from three models		355567-1	356326	355567-2
Primary (center-tapped)	turns (½ primary)	600	1,094	3,400
	Resistance (approx.)	30 ohms	450 ohms	750 ohms
	60 cps impedance	1,300 ohms	7,500 ohms	50,000 ohms
	Impedance, full pri.	5,200 ohms	30,000 ohms	200,000 ohms
Secondary	turns	9,600	17,500	12,000
	Resistance (approx.)	2,500 ohms	5,800 ohms	3,400 ohms
	Capacity to tune to 60 cycles	.015 mfd.	.001 mfd.	.003 mfd.
Weight		5.7 oz.	7.1 oz.	6 oz.

Prices from $21.00 (even more favorable on quantity purchases).

Amplifiers

As a basic link in the servo loop, the Brown amplifier converts a d-c input signal to ac, and amplifies the signal sufficiently to drive a two-phase balancing motor. Readily adaptable to various measuring, balancing, and positioning applications.

Select from these basic models

Gain	Sensitivity (Microvolts)	Nominal Input Impedance (Ohms)
10^6	4.0	400, 2200, 50,000*
4×10^6	1.0	400, 7000
12×10^6	0.4	400, 2200, 7,000
40×10^6	0.1	2200

*Special for high impedance sources.
Prices from $98.50 (even more favorable prices on quantity orders).
Reference data: Instrumentation Data Sheets 10.20-3 and 10.20-4.

WHAT'S NEW

Reelected President Henry Dever could cite a full year of gains by his Association* and the instrument manufacturing industry it represents. Some of the projects and progress ticked off . . .

A BOOMING MARKET: research and development—a big instrument user—is growing 10 to 12% a year

BOUNTIFUL SALES: industrial instrument sales are up 27% over '54; optical 19%; lab items 10%

BETTER STATISTICS: cooperation with Dept. of Commerce is producing fine market information

SAMA Posts Year's Progress in Instrumentation

BELLEAIR, Fla., April 8-13—Some dull, un-Florida-like weather failed to tarnish the spirits—or the attire—of the 410 instrument manufacturing executives and their wives who luxuriated at the Belleview-Biltmore hotel in this Florida resort. The occasion was the 38th annual meeting of the Scientific Apparatus Makers Association—the only organized industry group representing the products for measurement and control. The enthusiasm—aside from the sheer delight of getting away from the factory—was due to another kind of climate: the exceptional market climate which this small but choice group continues to operate in.

Henry F. Dever, newly reelected president of SAMA, and president of the Brown Instruments Div. of Minneapolis-Honeywell during routine working days, evoked this optimistic climate at the opening business session. With gross national product increasing at 3 per cent per annum, and with an estimated $6 to $7 billion slated for research and development by the end of '56, Dever saw a bullish market in the next several years for his industry. But the growing shortage of technical manpower and increasing sophistication of instrument systems, said Dever, could severely tax the capacity of the instrument maker to satisfy this expanding market. He cautioned those present to reexamine their forms of products, their policies, and their marketing techniques.

Meeting the Challenge

To the CONTROL ENGINEERING reporters who attended this meeting it was obvious that SAMA was well into a program to help its members meet this challenge of an expanding economy. One fruitful project has been its representation in the Federal Government's mobilization readiness program. Every six months SAMA appoints a man from its ranks to work, without compensation, as deputy to Nathan D. Golden, director of the division covering instrument products in the Dept. of Commerce. The present deputy, Cortlandt Van Rensselaer of Hewlett-Packard Co., will later join past deputies in an "executive reserve", the nucleus of a mobilization division in the event of war.

Oriented and spurred by contact with SAMA, Golden's division has started furnishing these services to its industry: valid marketing data; gradual disposal of needed surplus government property; promotion of exhibits; advice on pending legislation (e.g., Walsh-Healy Act); promotion of foreign trade (*Industry's Pulse* in the May issue of CtE was based on information developed by Golden's division). Other projects: studies of "essential" instrument components for defense (e.g., gyros, jewelled bearings); stockpiling of skills; weighing the need to geographically spread instrument making plants.

Deputy Van Rensselaer described a typical SAMA-Dept. of Commerce project: an industrial mobilization study on electronic test equipment. The steps involve—

1. Defining the scope of the field (there are approximately 300 companies with catalogs and buyers guides in this area).
2. Tabbing the size of plants and dollar volume of their business.
3. Determining types of electronic test equipment made by each company.
4. Obtaining industry advice to test the validity of incoming data.
5. Analyzing all information in the light of mobilization requirements.

A worthwhile, nondefense by-product of the above and similar studies has been the increasing improvement of Bureau of Census market statistics.

At its annual business session some new faces joined SAMA's group of section officers: Lyle Higgins of Gaert-

*L. to r. Earl R. Mellon (Weston Electric), meeting chairman; George W. Taylor (U. of P.) talk on labor relations; Dever; Nathan D. Golden (Dept. of Commerce) talk on government bureau activities; Cortlandt Van Rensselaer (Hewlett-Packard), SAMA deputy to Dept. of Commerce; W. C. Stevenson, SAMA Washington representative.

. . . and some of the congratulations

An award for Deputy Van Rensselaer . . . for past-Deputy Bob Clark (Powers Reg.) . . . and for SAMA pioneer Harold Richmond

ner Scientific Corp. is now chairman of the optical section, and Ray Olson, president of Taylor Instrument Cos., heads the recorder-controller section. Also, two new directors-at-large are on the SAMA governing board: L. B. McKinley of Bausch & Lomb, and G. A. Downsbrough of Boonton Radio Corp.

Many people who are interested in instrumentation and automatic control are not too familiar with SAMA—despite the fact that members of that organization have been prime movers in this technology for as long as a half century. This may be due to SAMA hiding its light under a bushel. The association contains only 217 member firms, yet represents an industry numbering over 2,000.

The recent meeting convinced our reporters that SAMA intends to "bring forth its light". It has studied the average size of firms in its industry and finds that "out of 539 companies, 460 employed between eight and 250 workers". This suggests that a future drive could make "association membership more attractive to companies of this size". In 1955 SAMA made a special effort to develop a radiation instrument group and the outcome is still pending.

With its new dynamism and the realistic picture it is developing of its scope it seems inevitable that SAMA will some day join the ranks of NEMA and other broad trade associations serving the major technical fields.

OTHER CONTROL CONCLAVES

Milan, April 8-13

One of the most comprehensive—and neatly organized—technical conferences ever held on the subject of "automation" took place on the above date in this industrious Italian city. The five-day session was sponsored by the National Research Council of Italy and drawn up under the direction of Prof. Algeri Marino, assisted by various Italian industrial groups and institutes. The main purpose of the meeting, according to the Italian trade press, was to "reach a clear understanding of the several problems connected with the introduction of automation in the several branches of industry and to collect a full documentation on these questions that will enable Italy to make a contribution to the International Symposium to be held in 1956 by the European Productivity Agency of the Office of European Economic Cooperation".

The conference, writes our reporter, was divided into three sections and ten groups. The first section considered "the scientific and technical basis of automation" and covered four areas: 1) unification of terminology and classifications; 2) the theory of automatic control (including analysis of control systems); 3) the technique of applying automation (including a session on system components, technical solutions, size regulation); 4) calculating machine technology. The second major section considered the "technical and economic opportunities for automation" and covered industrial production, public and private services, and automation in the organization of industrial groups. The third section dealt with the "social and economic effects of automation". It dwelled on problems of investment, international trade, national growth, as well as trade union reactions, labor shifts, and individual worker psychology. One added special session: "The School and Automation"—a look at the effects of automation on teaching programs.

Coincidental with this excellent program was a fairly sizable exhibit of equipment which was billed as "advanced developments in automation". Because of the time factor we were not able to get a complete report on the results of this important Milan conference into this issue. However, in the July issue look for a detailed analysis by two of our correspondents in Europe, John Hrones of MIT and Mel Fusfeld of Philadelphia.

Cambridge, April 4-6

Writes John Tunstall, Control Engineering's reporter out of McGraw-Hill's London, England, office, "I have just returned from three days at Cambridge University where I attended the Conference on Plant and Process Dynamic Characteristics which was arranged by the Society of Instrument Technology, Ltd. I was lucky to get to this affair, since it was preordained that all proceedings would be 'off the record' and the technical press was not invited. The reason for this was to get all the process boys together and have a 'no holds barred' contest between the instrument engineers, plant managers, designers, and applied mathematicians—with no record or restraint to mar the fun.

"Actually, there were no real fireworks, and with the exception of some controversy on terminology and the use of computers, the whole pro-

ceedings settled down to a splendid, sober, and important exchange of views by most of England's top people in this field. Altogether, eleven papers were presented, about half of which dealt with the dynamic behavior of heat-transfer surfaces — mainly distillation columns.

"The conference proper was preceded on registration day by a discussion on terminology which was designed to prevent the usual wrangling on this issue in later sessions. During a lively give-and-take the particular evil of process designers and servo engineers adhering to their own traditional jargon was emphasized. While this deadlock was hardly resolved, the consensus of the group was that a unified terminology project should be developed without delay.

Some of the papers

"The first paper, 'Dynamic Response of an Experimental Jacketed Pan', submitted by A. H. Horton (ICI), concerned an experiment purely to check a theoretical analysis. The next three all dealt with control of distillation columns using a pilot plant. Frequency response techniques were used and in most cases the author established simple hypothetical electrical R-C analogs. There followed a paper of more practical interest by Dr. Hengst (Badische Anilin & Soda Fabrik A.G.) on distillation control. Hengst's experiments were conducted on a fully operable 48-plate bubble-cap column to establish temperature response characteristics and the optimum controller position. One control system investigated had the control valve in the reflux line and the detector placed in different positions on the column. Cyclic movement was imposed on the valve until the whole column was excited harmonically. The temperature response of the plates was observed and frequency response curves plotted.

"While the quality of the analytical and experimental techniques described in these papers was acknowledged, there was a general feeling expressed that treatment seemed to stop short of the real requirement, which was to provide data whereby commercial plants could be built and operated. As one leading worker implied, there is no virtue in establishing defining equations based on nefarious assumptions and then proceeding to build a model plant to verify them. And the reverse, in which an experimental plant is built and a theory found to suit it, is no better, if it does not also produce correlation data on which the plant designer can operate. On the other hand, the applied mathematicians were quick to define the purely analytical approach which, it was agreed, should be fully exploited before money goes down the drain.

"The validity of the assumptions made by several of the speakers was fairly widely argued. It was also pointed out that most workers were using binary liquids when, in fact, the process had to deal with multicomposition liquids, the effect of which might be considerable. But it was not until an instrument firm representative revealed the use of a digital computer in this field of investigation that the conference began to ponder whether Britain was using this powerful but expensive tool anywhere near sufficiently. According to this speaker, most of the assumptions to which members had objected became unnecessary if a digital computer was available during the analysis.

"The question of adopting the right tools broke out again during the presentation of the last paper, 'Data Reduction as a Tool in Plant Analysis', by C. A. Laws (Elliot Brothers, Systems Div.). Laws seemed to admonish the group for its attitude toward data reduction, which he said was unknown in Britain, yet well-established in the U. S. He went on to describe the techniques involved, and emphasized the function of collecting off-normal information, an operation he said was badly needed at the moment. He admitted the cost was high.

Revamped values needed

"Summing up, it was difficult not to be impressed with the caliber of the young talent Britain has mobilized in this field. But, overall, one got the feeling that she is not doing full justice to this unique talent by starving it of much needed equipment. With this she could banish longhand methods and analytical drudgery, which fritter precious hours away."

(Editor's note: Tunstall indicated that the second part of a paper at this conference, by H. Voetter of Royal Dutch Shell, was considered a major contribution to the literature on distillation-column control operations. His abstract of this paper can be found on page 159 of this issue.)

New York, April 3

Senior Associate Editor Byron Ledg-

erwood recently spent a rewarding day at a special Technical Forum on Guided Missiles sponsored by General Electric in a meeting room of the Hotel Commodore. "GE," writes By, "feels that there are many problems in the development of guided missile systems that could be more quickly solved if they were publicly presented to a diversified group of guided missile experts. Hence they arranged this forum to air what they felt to be the most pressing missile problems, and invited scientific and engineering people who would be interested, and who might possibly originate ideas for meeting these problems during floor discussions.

"GE got a packed house—about four to five hundred top quality people came. But while the audience was obviously good, I wonder whether GE got the technical boost it was after. Most of the comments from the floor seemed to be questions and were not contributions to solutions to the problems that were posed. Of course, it is quite possible that ideas were also generated during the individual discussions at the close of the meeting.

"GE splits the overall missile system into propulsion, guidance, and airframe subsystem. It is interesting to note that the major problem today is in the airframe system, and not in guidance or propulsion. This was a direct answer to a question I asked (yes, I was one of the guilty noncontributors). It seems rather obvious, since the two highly technical papers delivered were both on airframe problems. GE scientists feel that if they can build a projectile with their present knowhow, they can drive and guide it.

"The problems of shock, heating, unusual air behavior, skin material, etc., become overriding considerations at speeds over mach 10. The obvious question is, why not drive the missile at lower velocities, eliminating many of these problems and using some of the proven guidance and propulsion means? This was pointed out to me by Dr. Robertson, of GE Systems Engineering, as being a simple physics problem. If you are going to drive a ballistics missile a certain distance, then you must shoot it off with a minimum 'muzzle' velocity. To be able to deliver a missile in the U. S. to points halfway around the world, this 'muzzle' velocity is far above mach 10, going up as high as mach 25. Thus, to be able to build a satisfactory ICBM they must be able to build an airframe that can stand velocities in the area of mach 20.

"The other choice is to build a missile such as Snark, which is rocket-driven on take-off, and then jet-engine-driven at altitudes at about 30,000 ft. Hence this is a jet- or ram-jet-driven missile with maximum velocity of about mach 1. These so-called 'air breathing' missiles are limited in speed by their propulsion means. The ICBM is needed because of the ease of knocking down these low-level flying missiles.

"The conclusion seems to be that the major problems in guided missiles today are not in control system design but, rather, in the aerophysics of the airframe. I didn't realize much of this before . . . and perhaps many of our readers are in the same boat."

GE's STAKE IN PROPULSION RESEARCH: These two buildings are concrete (and brick) proof that the General Electric Co. is dedicated to the future of new forms of energy in air-propelled vehicles. The one on the left, the first facility for the company in this field, is the Lynn, Mass., Aircraft Gas Turbine Lab, erected in 1950. On the right is the latest: the new computer building at Evendale, Ohio, which is hooked up on leased telephone lines with Lynn and does the calculations on research projects. By 1960 GE will have sunk $100 million into its propulsion research program.

Two Major New Entries in the Digital Sweepstakes

One is a remarkably compacted miniature of a famous computer. The other is an updated data processor that draws on computer techniques for flexibility. Both are hot prospects for process control . . . and both are prime examples of the feverish pace of digital evolution.

Prof. J. Presper Eckert is activating the input typewriter and Dr. John W. Mauchly is pointing at readout lights as RemRand's new computer works a simple problem. Oh yes, that's our Lloyd Slater standing between these two eminent inventors of UNIVAC.

Ralph Webb (left) director of instrumentation of Carbide & Carbon Chemical Co., looks over the new Beckman Data System during recent 3,000-mile demonstration tour. At right is Taylor Fletcher, manager of Beckman's Data & Control Systems Dept.

Early this spring two new items blossomed in the digital equipment field. Unlike a horde of other emerging equipment, these were not minor variations on an old theme. They were machines with a distinct and intriguing new generic quality—and the interest they attracted proved the quality was a good one. The items:

▶ a "pinboard-memory"-equipped data logger by Beckman Instruments, Inc.

▶ a solid-state, pint-sized version of UNIVAC by Remington Rand

Beckman was the first to announce its new baby—the Beckman Data System (CtE, April '56, p. 111). During March it took the system on a cross-country tour for private demonstrations to engineers in Indianapolis, Charleston, W. Va., and Wilmington, Del. Besides the new logger, the display rig included a working graphic panel to represent a typical industrial process and an automatic typewriter for logsheet readout.

Set up in hotel rooms, the Beckman system would digest data from the graphic panel—flashing lights indicating a sensing element pickup—while the typewriter would log the data out. Visitors were invited to submit representative data-handling problems and these were programmed on the pinboard to demonstrate this new feature. In one two-hour period the system was programmed for 30 separate sets of process variables.

CONTROL ENGINEERING's reporter managed to take in the final leg of the demonstrators' journey before the system's installation at Esso's Baton Rouge, La., refinery. In the Alchemist Room of the Hotel du Pont, he reports, "there was excellent attendance from du Pont, Sun Oil, David Taylor Model Basin, Atlantic Refining, Pratt & Whitney, Tidewater Oil, M. W. Kellogg, and Bureau of Ships. All seemed keenly interested."

Enter—the "Baby UNIVAC"

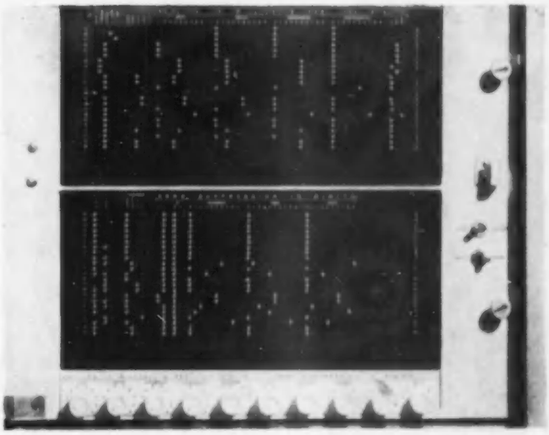
Remington Rand's coming-out party for its new computer was more spontaneous and unrehearsed. The machine had been under secret development for several years and the first model was about to be delivered to the Air Force Cambridge Research Center—when the military relaxed and offered to let the press have a look. So on one day's notice a CtE reporter entrained for Philadelphia. There, guided by RemRand leading lights, Drs. Eckert and Mauchly, he was exposed to "Baby UNIVAC."

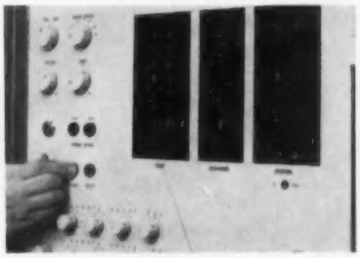
Our man was impressed. The arithmetic and memory section of the new machine is housed in a neat cabinet 6 ft high, 6 ft, 6 in. long, and 18 in. deep. Its operating console, including paper tape, input-output unit, and direct entry typewriter, is a mere 4 ft by 6 ft by 3 ft. Inside the cabinet are 1,000 magnetic amplifiers (the company designed and builds these . . . calls them *Ferractors*) and 30 vacuum tubes. These perform the same functions as 5,400 vacuum tubes in UNIVAC. Another neat feature: a 16,500-rpm magnetic drum memory with four spaced reading heads.

Because of its remarkably simplified construction, yet great capability, RemRand believes that the prime market for its new computer will be process analysis and control.

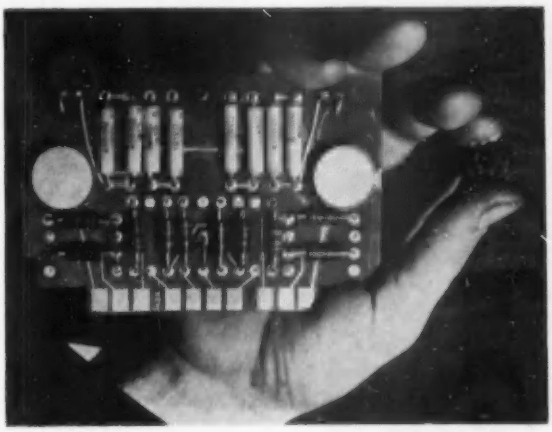
HOW THEY FUNCTION

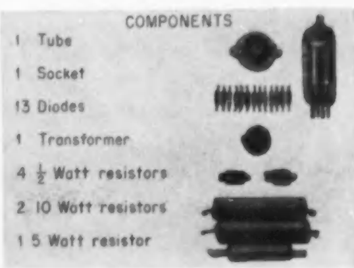
1. THE BECKMAN DATA SYSTEM features a digitally controlled grouping "pinboard" (right), which permits the operator to alter or employ such functions as linearization, input scaling, integration and digital summation, alarm limits, selective output control. The readout panel flanking the "pinboard" (lower left) displays time, channel number, and signal. Earlier Beckman Div. data-handling systems used telephone relays, slide-wire balancing mechanisms, and coding wheels. The new design—a product of two years of research—stresses reliability: the center picture below shows the stepping-switch assembly which is immersed in oil and hermetically sealed. Visible in the background of the picture on the right (below) is the 60-cycle chopper amplifier and the mercury type plug-in relays, which function with a sealed an-dig converter. All units plug in and Beckman advises that the cabinet of the basic 50-channel unit contains enough room for another 50 channels—that is, one more stepping switch and pinboard array. The system is ungrounded to eliminate ground loops.

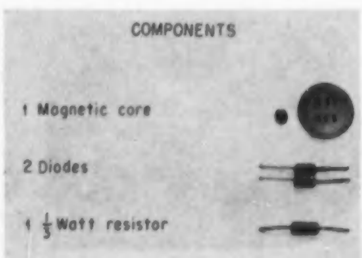




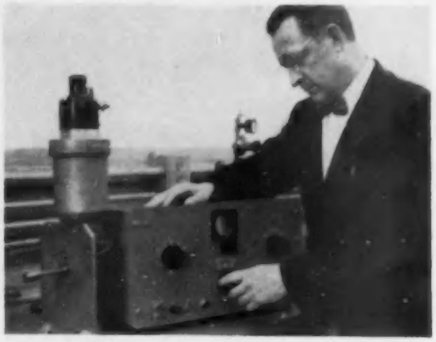
2. REMINGTON RAND'S UNIVAC MAGNETIC COMPUTER features a "postcard" printed-circuit assembly (right). About 600 of these, plus a few transistors, form the main arithmetic part of the system, which has a computing capability equal to UNIVAC. Note the plug-in pulse-amplifying *Ferractor*. These are inside the "pots" on the card—two per pot. To get an idea of the space-saving and simplification involved, study the two pictures on the left below. Using *Ferractors*, 1 core, 2 diodes, and a resistor functionally replace 23 parts in a conventional computer circuit. Another remarkable innovation is the compact, high-speed magnetic drum memory (below, right). The drum has a special nickel-cobalt surface and is sealed in helium for more effective heat transfer. The four reading heads, 90 deg apart around the drum, achieve the effect of increasing drum speed to a phenomenal 66,000 rpm. The new computer's capability: addition of two 10-digit numbers in 90 microsec; more than 11,000 additions per sec; multiplication in from 0.3 to 1.7 millisec, or over 3,000 multiplications per sec.







WHAT'S NEW



ECKMAN ON COMPUTER PROCESS CONTROL: A key speaker at the ISA Computer Symposium will be Dr. Donald P. Eckman, professor of instrumentation engineering at Case Institute of Technology. Don will describe the integration of computers into the processing system. He's shown here testing a pneumatic valve actuator with a frequency function generator. Similar frequency response tests were part of the pioneering Case project to set up a computer-controlled hydrogenerator.

CONCLAVES TO COME

New York, Sept. 17-21

From all reports received in this office to date, the forthcoming national meeting of the Instrument Society of America will be one of the most significant and rewarding events for control engineers in a very rewarding year. This fall the exhibits and technical sessions will be housed in New York's handsome new Coliseum, on Columbus Circle at 59th Street and Broadway. The facilities are superb: excellent display space and large, air-conditioned meeting rooms. Other incentives to attend include:

▶ over 500 exhibits of new control field products fitting all parts of the loop. Among them: a large array of displays from England, Germany, The Netherlands, Italy, France.

▶ a technical program comprising 200 papers: a unique thing about the ISA program is that the papers are highly practical and closely oriented to automatic control, and deal with real problems in industry and the military

▶ an all-day computer symposium that promises to state clearly and logically the function of the computer in the control of an industrial process

▶ "shirtsleeve" clinics, which will be run in special rooms off the exhibit floor; they'll cover instrument maintenance, data-processing systems, and analytical instrument techniques.

▶ a splendidly organized two-day session—cosponsored by the American Rocket Society—which will tick off progress in coping with problems posed by the forthcoming Geophysical year, particularly measurement and control of the Earth Satellite.

▶ control system design work taken from the laboratory benches of eight universities and manned by the graduate students who did the work. This exhibit was organized by CONTROL ENGINEERING editors and is cosponsored by this magazine and the ISA.

We are told by ISA that the technical sessions will be augmented by social functions, plant tours, and the usual rounds of friendly hospitality sponsored by control manufacturers. And that the New York Host Section Ladies have rigged up an exciting week for their sex, including a fashion show, a boatride up the Hudson, a matinee, and a day at West Point.

It looks to us like the working control engineer can hardly afford to miss this event (we also hope he can bring his wife). We'll be looking for you in New York next fall.

Paris, June 18-24

T. J. Higgins writes us that a symposium on "Automation" will be held in this delightful city on the above dates. He says the program will cover Theory (definition; electronic and mechanical aspects; domains of applications in engineering, science, and economics) and Practice (functional and technical structure of "automating" production; domains of application; technical, social, and economic influences of "automation" on production). He suggests that anyone interested in the symposium—and in seeing Paris in the spring—contact Secretariat du Colloque sur l'"Automatique", Chaire de Mecanique, Conservature National des Arts et Metiers, 292 rue Saint-Marten, Paris (IIIe). The meeting is cosponsored by the Association de Ingenieurs Electroniciens and Societe des Radioelectriciens.

Cambridge, Summer '56

A flock of announcements fresh from this Boston suburb indicates that MIT is once again conducting an elaborate series of short summer courses with excellent content for the control engineer. They include:

▶ June 18-29—a two-week seminar in "Dynamic Measurements" directed by

PRECISION IS OUR BUSINESS

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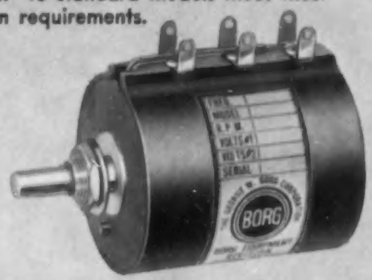
series

The new standard of high-precision potentiometers. Advantages include greater accuracy, finer resolution, lower torque, longer life and better performance under adverse environmental conditions. 48 standard models meet most special design requirements.



1100
series

Precision potentiometers that offer your products a price advantage in today's competitive markets. Engineered for easy installation with readily accessible terminals. Accurate, dependable, long lived.

205
series

Long a favorite for both military and commercial purposes. Has proved itself exceptionally rugged and dependable in years of use on many mobile and stationary applications.

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precision potentiometers with

UNLIMITED DESIGN APPLICATIONS...
MORE PROFITABLE PRODUCTION POSSIBILITIES

Your job is made easier when you use Borg Micropots. They're versatile . . . they're flexible. Standard models can be readily adapted to meet the special requirements of a wide variety of applications. What is more they have many exclusive advantages: — — absolute linearity, permanent accuracy, long life, and dependability. You can rely on them to meet your most rigid commercial and/or military specifications. They're readily available too. Production has been stepped up to assure prompt delivery of any model in any quantity. We invite consultation with your Borg "Tech-Rep". His helpful advice can often save you time and money. Write us today for his name and address. It will pay you to know him.

BORG EQUIPMENT DIVISION
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ELECTRONIC — MECHANICAL BORG EQUIPMENT

Built by Borg

WHAT'S NEW

Dr. Yao Tzu Li, associate professor of aeronautical engineering.

▶ July 16-27 — a two-week special program on the "Theory and Practice of Ceramic Forming". Professors Norton and Kingery will supervise and guest speakers will be brought in from England and Australia, as well as from advanced digital component manufacturing plants here.

▶ July 30-Aug. 10—a two-week course in "Control System Engineering" directed by Dr. Bill Seifert of the Dynamic Analysis & Control Lab.

▶ July 9-20—a two-week special course on "Recent Developments in Fluid Power Control" administered by Dr. J. Lowen Shearer and Dr. Freddie Ezekiel.

▶ Aug. 6-10; Aug. 13-17—two short courses on "Electronic Data Processing" conducted by Dr. Robert Gregory. The first week will cover electronic computers and business problems, the second the use of data processing by management.

▶ Aug. 13-17—a course conducted by Alfred K. Susskind on "Analog to Digital Conversion Techniques".

If you want more details on any of these courses write directly to Prof. E. H. Huntress, director of the MIT summer session, Cambridge 39, Mass.

Detroit, Summer '56

Wayne University also seems to be building an excellent summer curriculum—especially for digitally minded management people and technicians who wish to train in computer techniques. Dr. Arvid W. Jacobson writes us that his Computation Lab will run three-week long courses:

▶ July 23-28—"Automatic Computers—Their Application and Evaluation"

▶ July 30-Aug. 4—"Electronic Data Processing in Business and Government"

▶ Aug. 6-11—"Applications of Computers to Engineering, Science, and Industry"

For more information, write to A. W. Jacobson, director, Computation Laboratory, Detroit 1, Mich.

Purdue, July 9-20

This year Purdue's annual conference on systems engineering will be an intensive 10-day short course devoted to "Linear Automatic Control System Synthesis". It is intended for engineers interested in advanced work. More information is available from the Div. of Adult Education, Purdue University, Lafayette, Ind.

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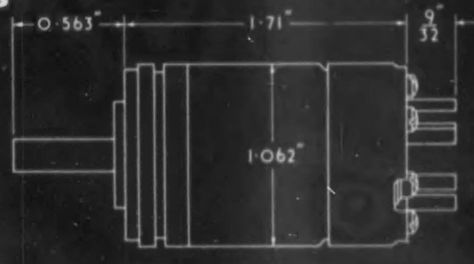

MUIRHEAD

F11 M-1-A/1 SIZE 11 CONTROL TRANSMITTER — **U. S. Bureau of Ordnance Number 11 CX 4a MARK 41 MOD. 1.**

Supply 115V 400c/s — Nominal Rotor/Stator voltages 115/90V

MECHANICAL DATA

BEARINGS	Single row ball journal bearings
ROTOR CONNEXIONS	Silver strip brushes, Silver slip rings
MAXIMUM FRICTION TORQUE (at room temperature)	0.05 oz in 3.5 gm cm
ACCURACY (MAXIMUM ELECTRICAL ERROR)	7 minutes
MOMENT OF INERTIA OF ROTOR	0.014 oz in^2 2.5 gm cm^2
WEIGHT	4.2 oz 120 g

Shaft splined and threaded to enable gear to be fitted.

ELECTRICAL DATA

INPUT Rotor

WINDING	Single phase
NO LOAD CURRENT	0.03A
NO LOAD POWER	0.7W
IMPEDANCE AT 115V 400c/s	700 + j 3700 ohms
D. C. RESISTANCE	445 ohms

OUTPUT Stator

WINDING	3-phase star connected
VOLTAGE BETWEEN TERMINALS (No Load)	90V max
RESIDUAL VOLTAGE AT NULL POSITIONS	
FUNDAMENTAL COMPONENT	45mV max
TOTAL RESIDUAL	75mV max
IMPEDANCE BETWEEN TERMINALS AT 90V 400c/s	490 + j 2520 ohms
D. C. RESISTANCE BETWEEN TERMINALS	300 ohms

MUIRHEAD

F11 M-2-A/1 SIZE 11 CONTROL TRANSFORMER — **U. S. Bureau of Ordnance Number 11CT 4a MARK 24 MOD. 1.**

Supply to energizing synchro 115V 400c/s — Nominal Stator/Rotor Voltages 90/58V

MECHANICAL DATA

BEARINGS	Single row ball journal bearings
ROTOR CONNEXIONS	Silver strip brushes, Silver slip rings
MAXIMUM FRICTION TORQUE (at room temperature)	0.05 oz in 3.5 gm cm
ACCURACY (MAXIMUM ELECTRICAL ERROR)	7 minutes
MOMENT OF INERTIA OF ROTOR	0.014 oz in^2 2.5 gm cm^2
WEIGHT	4.2 oz 120 g

Shaft splined and threaded to enable gear to be fitted.

ELECTRICAL DATA

INPUT Stator

WINDING	3-phase star connected
SUPPLY FROM TRANSMITTER PER PHASE	90V maximum
CURRENT PER PHASE	12mA
IMPEDANCE BETWEEN TERMINALS AT 90V 400c/s	1250 + j 7400 ohms
D. C. RESISTANCE BETWEEN TERMINALS	535 ohms

OUTPUT Rotor

WINDING	Single-phase
VOLTAGE ACROSS 20,000 OHM LOAD	1V per degree initial misalignment
RESIDUAL VOLTAGE AT NULL POSITIONS	
FUNDAMENTAL COMPONENT	30mV max
TOTAL RESIDUAL	60mV max
IMPEDANCE AT 58V 400c/s	680 + j 3200 ohms
D. C. RESISTANCE	370 ohms

Copies of the above data together with mounting instructions may be had free on request by writing to the address below.

MUIRHEAD

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All Around the Business Loop

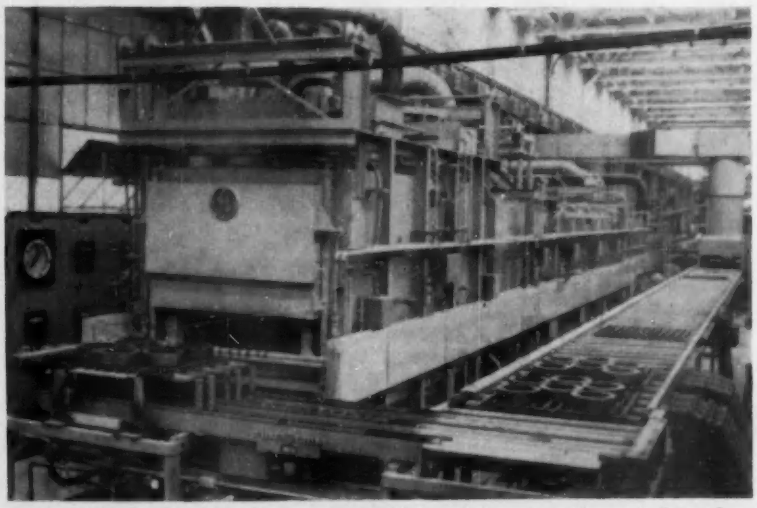
From the outside, Building 85 looks like any other quarters on General Electric's vast industrial plantation in Schenectady, N. Y. But the inside of the plant has been tooled up for a method of production that some call automation, and that GE prefers to call "mechanization". Chosen as the end-product of the new technology is GE's well-established Tri-Clad "55" motor, an induction-type motor that, according to O. F. Vea, general manager of the Medium Induction Motor Dept., is designed to serve "automated" industry. "And," says Vea, "it is only logical that the shoemaker's son should wear shoes."

The Tri-Clad, so named because it is baked three times, once in varnish, once in paint, and once in silicone, starts out at one end of the plant as stator and rotor laminates, and snowballs through in three eight-hour shifts. On the way it is handled by machines that GE has either built itself or had built to its own specifications. One of GE's own creations is a single-pass annealing furnace that takes on hundreds of stator and rotor punchings every hour. One of its imports: a National Automatic Tool Co. multi-station transfer machine, which does all the boring, drilling, and tapping on the cast-iron stator frames. The company had to go elsewhere, too, for its punch presses (Niagara), pressure-casters (Douglas), dynamometers (Toledo), rotating-table testing machines (Wilson), and a few more, but every one of them was a GE design.

In applying a singularly simple idea—using a solenoid valve to control shield feed—GE gave a hint at where it stood on the subject of automation: machines don't have to be fancy, but they do have to produce. That may be one of the reasons the winding operation on the Tri-Clad remains a manual process. It's not a sore point with GE. As Superintendent of Manufacturing J. R. Olin implied at a press conference marking the plant's new interior, an economical way to do the job automatically just hasn't arrived. Thus winding involves the highest amount of direct labor in Building 85.

But the number of human hands involved in start-to-finish process has been cut considerably. A word concerning the number of maintenance people in the plant came out during a question and answer period to indicate this. There was no announced change in the number of maintenance people themselves, and yet the ratio of the number of them to the number who actually run the machines has undergone a momentous change: from 4:1, when plant-redesign started (about 1948) to 8:1 today!

The Tri-Clad motor built in Building 85 puts out between 7½ and 30 hp. Supervising the 600 people who work on it are, besides Vea and Olin, G. A. Cook, manager of the Low Integral



AUTOMATIC ANNEALING—Just a corner of the automatic control panel shows in this view of General Electric's multi-zone continuous annealing furnace for rotor and stator punchings. It's one of the features of the company's new Schenectady motor plant.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... With five types of parallel and right angle Gearmotors, Master has the flexibility and choice of design you need for selected output speeds.
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... And that's why more gearmotors carry the Master name than all other makes combined. Write on your business letterhead for details.
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Parallel Shaft Type
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THE MASTER ELECTRIC COMPANY
Dayton 1, Ohio

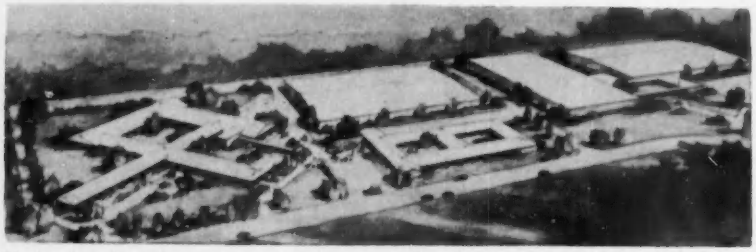
Horsepower Product Section of the Medium Induction Motor Dept., and W. M. Schweder, manager of engineering for the $7-million plant.

Someone at the Q&A session asked these men if, after all the work GE has put into its developments at Schenectady, the company planned to stay there. Yes, they said, looking at the questioner somewhat sympathetically, they supposed it would.

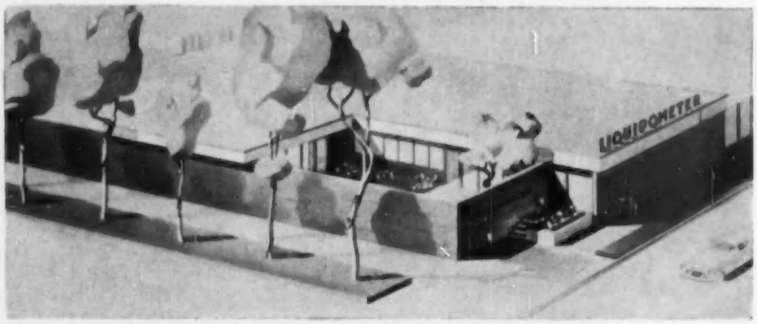
▶ The Army's Redstone is one of several guided missiles being developed and tested by industry under Defense Dept. contracts. As it has done with its other missiles, the Army has awarded contracts on various phases of the Redstone to different private companies. One of these is **Ford Instrument Co.**, which is handling the Redstone's guidance system. When the Defense Dept. set up new agencies to grapple with problems posed by shorter time schedules and longer-range missiles, Ford was prepared to tackle the larger chores sure to be tossed its way.

Fully primed is a new **Missile Development Div.**, whose eight-man management staff will supervise all engineering, developmental work, experiments, and tests associated with the Redstone. All facilities for these phases, together with a modification center and a field service headquarters,

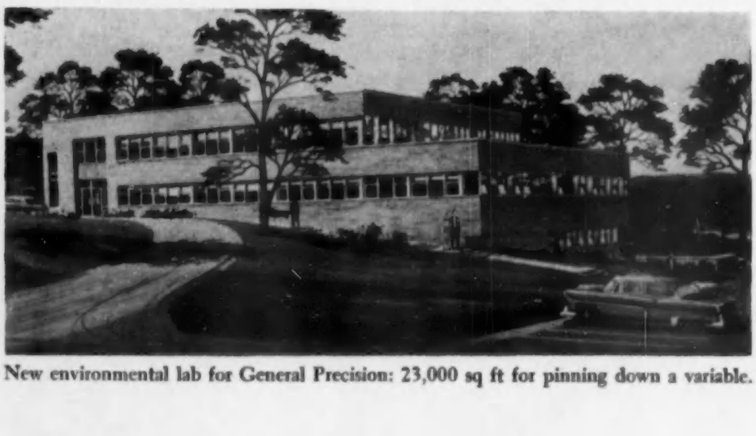
PLANTS A-BUILDING



Varian Associates draws up a master plan: expanding divisions to get their own buildings.



An instrument hospital on the coast: Liquidometer Corp. builds 3,000 miles from home.



New environmental lab for General Precision: 23,000 sq ft for pinning down a variable.

have been moved into a newly-leased building in Long Island City, N. Y. Manufacture and assembly of the guidance system continues in Ford's two other Long Island plants, and in one of these the company has built a gyroscopic test laboratory for missile-gyro experiments.

Manager of the new division is Lawrence S. Brown, who has been


L. S. Brown


L. J. Scheuer

with Ford since 1934 except for a year as sales manager for **Bulova Research & Development Laboratories, Inc.** Brown, who holds patents in fire control systems, bomb-release computers, aircraft computing sights, and gyroscopic mechanisms, was a staff project engineer before his appointment. Lewis J. Scheuer, Brown's director of engineering, joined Ford in 1948. In 1954 he was assigned engineering responsibility for the Redstone's guidance system, and in that same year conducted a missile velocity system study for the Signal Corps.

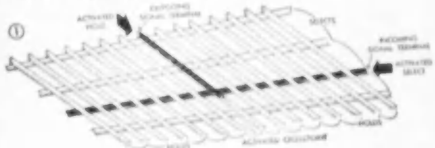
Filling out the division's staff are Carl S. Backman, manager of test; John J. Woodruff, chief of the modification center; Lawrence W. Farrell, production manager; Henry J. Kreisselmeier, shop manager; James E. Campbell, contact supervisor; and Norman R. Gilino, Ford liaison man at Redstone Arsenal, Huntsville, Ala., all previously with Ford, and Allen T. Schwab, formerly personnel director of Bulova R&D Labs, who takes on similar duties at Ford.

▶ Last January **American Telephone & Telegraph Co.** consented to a government decree ordering release of AT&T's 8,600 patents (CtE, March, p. 30). The news was right up the alley of the control field. Last April 18, AT&T made news again, and again the figure involved was imposing. This time AT&T announced it would spend $2.1 billion on construction in the next year, making it the first company in history to lay out more than $2 billion in this length of time. The company's Bell network recently established, in San Diego, Calif., the nation's first coast-to-coast

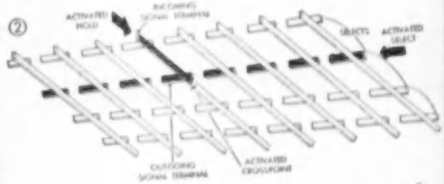
IT WILL SAVE YOU TIME AND MONEY TO ADD "CROSSBAR" TO YOUR AUTOMATION VOCABULARY

crossbar (krôs′bär″)

The most modern, compact, fast, and economical means of concentrating hundreds of relay or switching operations for practically any automatic control, computing, reporting or sequential sampling operation.

① 

The basic Crossbar principle which permits any of several incoming circuits to be connected to any of several output circuits is illustrated above. This switch actually can connect any of 60 circuits, 3 at a time, to any of 75.

② 

The drawing above shows a means of switching one incoming circuit to many possible outgoing circuits. This type of switch can easily be adapted to switch one circuit to as many as 936 circuits.

Here is why Crossbar takes the place of Relay Tree in your automation vocabulary: With the Kellogg Crossbar several switching operations can be carried on independently at the same time . . . entire switch can be mounted in drawer-type frame for easy inspection . . . contact material is palladium (or gold) . . . any crosspoint can be activated in less than 50 milliseconds.

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Kellogg engineers will show you how Crossbar advantages will work for you. Saves design time.

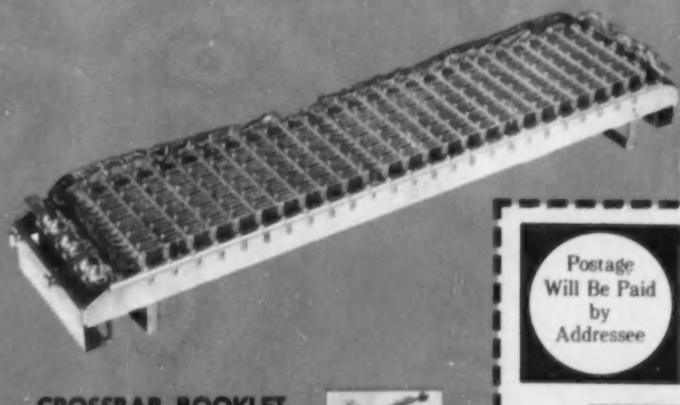
ADAPTABILITY

Kellogg Crossbar has been adapted to a wide variety of industrial applications.

ECONOMY

Kellogg Crossbar:

- Requires practically no routine maintenance
- Is equivalent to a bank of relays, assembled, mounted, and partially prewired
- Uses less hardware
- Uses fewer coils
- Consumes less power



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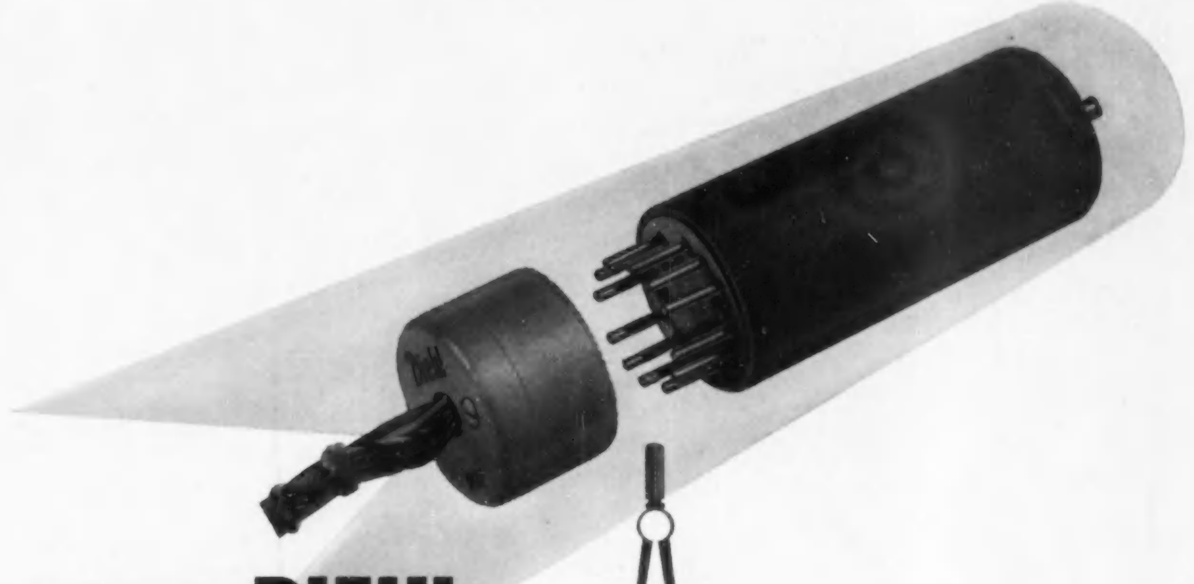

THIS NEW **DIEHL** SIZE 11 RESOLVER SETS A new standard of Accuracy...

. . . a new low in total functional error for a Size 11 Resolver—0.05%! An entirely new design concept permits complete machine-winding of the units, with resulting high uniformity of product and performance. Other novel design features enable the resolver to withstand altitudes of 70,000 feet without pressurization.

There are three types . . . *with high impedance,* permitting the primary to be excited with 110 volts at 400 cycles . . . *with low impedance,* when higher frequency response is desirable . . . and *compensator wound* for temperature and frequency variations.

These types are obtainable, each with 2 input and 2 output windings, in either Class I Design with 0.05% maximum total functional error or Class II Design with a maximum error of 0.10% where less accuracy is tolerable and lower cost is desired.

All resolvers are equipped with pin-type terminals. Mating plugs can be supplied for convenient connection to computer circuits.

Take a look at the Class I specifications. Note the new opportunities they offer to satisfy unusual application needs.

CLASS I SPECIFICATIONS

DIEHL NUMBERS	B11R1-1	B11R1-5	B11R1-6	REMARKS
Type	Low Impedance	High Impedance	Compensator Wound	
Total Functional Error	0.05%	0.05%	0.05%	
Input Impedance (ohms)	750∠80°	3000∠80°	1500∠78°	±10% on ohms ±2° on angles
Effective Resistance (ohms)	3,000	12,000	5,500	when resonated
Transformation Ratio	0.975∠6°	0.975∠6°	0.975∠6°	±0.02 on ratio ±1° on angle
Max. Null Voltage (m. v./volt input)	1.0	1.0	1.0	Quadrature
Weight (ounces)	4.7	4.7	4.7	

Patents Pending

All measured data above taken at standard test voltage of 10 volts at 400 cps.
Case and shaft supplied with reference markers.

other available components

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DIEHL MANUFACTURING COMPANY
Electrical Division of THE SINGER MANUFACTURING CO.
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GE6-56

telephone dialing system for big-city subscribers. It plans to set up Hartford, Conn., for the same service in June.

► Within the space of one April week, two governments—the U. S. and Canada—awarded electronics contracts to **Raytheon Mfg. Co.** The contracts, for more than $51 million, call for Raytheon to produce airborne electronic equipment for the U.S. ($46 million) and to develop and manufacture radar installations for 15 Canadian airports ($5 million). The U. S. contract is one of Raytheon's largest in recent years. Features of Raytheon's Canadian project (Airport & Airways Surveillance Radar) are a 40-ft antenna providing a 200-mile-wide, 70,000-ft-high scanning range, and choice by the operator of either linear or circular polarization of the radar signal.

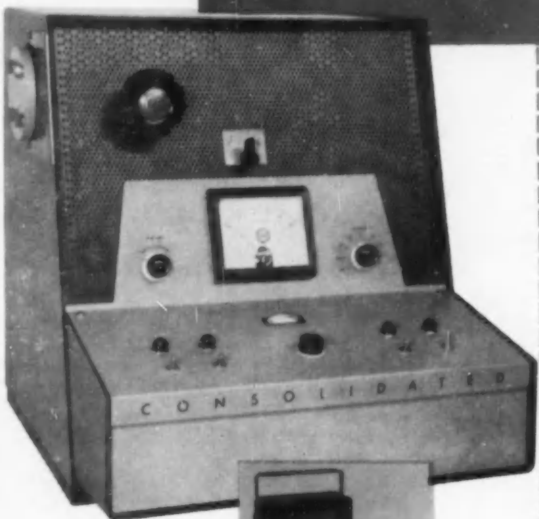
► **ElectroData Corp.'s** Datatron digital computer, which last New Year's Day gave the one-two (binary, that is) to two-legged football prognosticators (CtE, March, p. 12), has pointed its indefatigable digits at baseball. After scanning performances of all 16 major-league teams over the past three seasons, it printed out this prediction: Detroit in the American League, dogged by Chicago and New York; and Brooklyn in the National League, followed by Cincinnati and New York. If Datatron is right, Detroit will have an easier time with New York than with Chicago, although respective odds on Detroit and Chicago taking the pennant are 40-1 and 9-1.

► Convair's new dynamic shock-testing machine, which reduces drop towers to golf-bag size, will be manufactured and sold by **Consolidated Electrodynamics Corp.** Additional features of the hydraulic instrument: application of widely varying forces for controlled periods, building-block assembly for specific problems, simultaneous firing of several accelerators.

► **Clary Corp.'s Automatic Controls Div.**, which handles the guidance end of the Corporal, Navaho, and other missiles, has taken on a batch of new orders. To enable it to handle the influx, Clary has expanded the division's production and engineering facilities and made the following appointments: Benjamin Ohannesian to assistant manager for the new Operations Section; Jay Borden to chief engineer, and James Gorner to chief production engineer for the new Production Engineering Section. The division's versatility has increased along with its production rate and

here's new convenience, new economy in positive leak detection...

Consolidated's new type 24-210 leak detector



Everything offered by previous CEC Leak Detectors . . . *plus* new simplicity, new convenience, and a startlingly low price. That's the story in a nutshell of Consolidated's new Type 24-210 Leak Detector, newest instrument from the company that made mass-spectrometer leak detection practical. It's usable wherever perfect seals are essential in the production of electronic components, in testing glass-to-metal seals, checking welded or soldered joints, locating or determining the size of leaks in *any* evacuated or pressurized system. It is extremely simple to operate . . . just plug it in and start it; there is no extended pump-down period, and no special training or experience is needed.

In research, maintenance or production, to combat leaks safely, positively, and economically, check these features of the new 24-210 Leak Detector . . .

- **No cold trap, no charcoal trap** . . . requires no attention, no filling with refrigerants.
- **Positive interlocks** . . . to prevent instrument damage due to improper operation.
- **Highly sensitive** . . . detects one part of helium probe gas in 300,000 parts air.
- **Convenient** . . . all controls on front panel; all electronic components readily accessible.
- **Highly simplified** . . . etched circuits for compactness and reliability; only six tubes in entire chassis.
- **Compact and portable** . . . measures only 18½" wide x 22" deep x 20½" high; weighs only 145 lbs . . . perfect for bench-top operation; plugs into 115-volt, 60-cycle line.
- **Economical** . . . uses little power; helium gas only operating supply needed.
- **Low cost** . . . achieved through advanced design; quality, dependability maintained at highest level.

Accessories to increase the 24-210's convenience and usefulness include: Sampling Probe (right) for pinpointing leaks in pressurized systems; Audio Alarm (above right) which provides audible signal whose pitch varies with the size of the leak; Mobile Workstand (extreme right) which carries instrument, provides work table, drawer facility, and lower shelf for mounting auxiliary vacuum system.

Send today for a complete description of CEC's new 24-210 Leak Detector. Ask for Bulletin CEC 1830-X7.

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capacity, and new, high-speed tool machinery soon will be moved into its twice-as-large Design & Development Section.

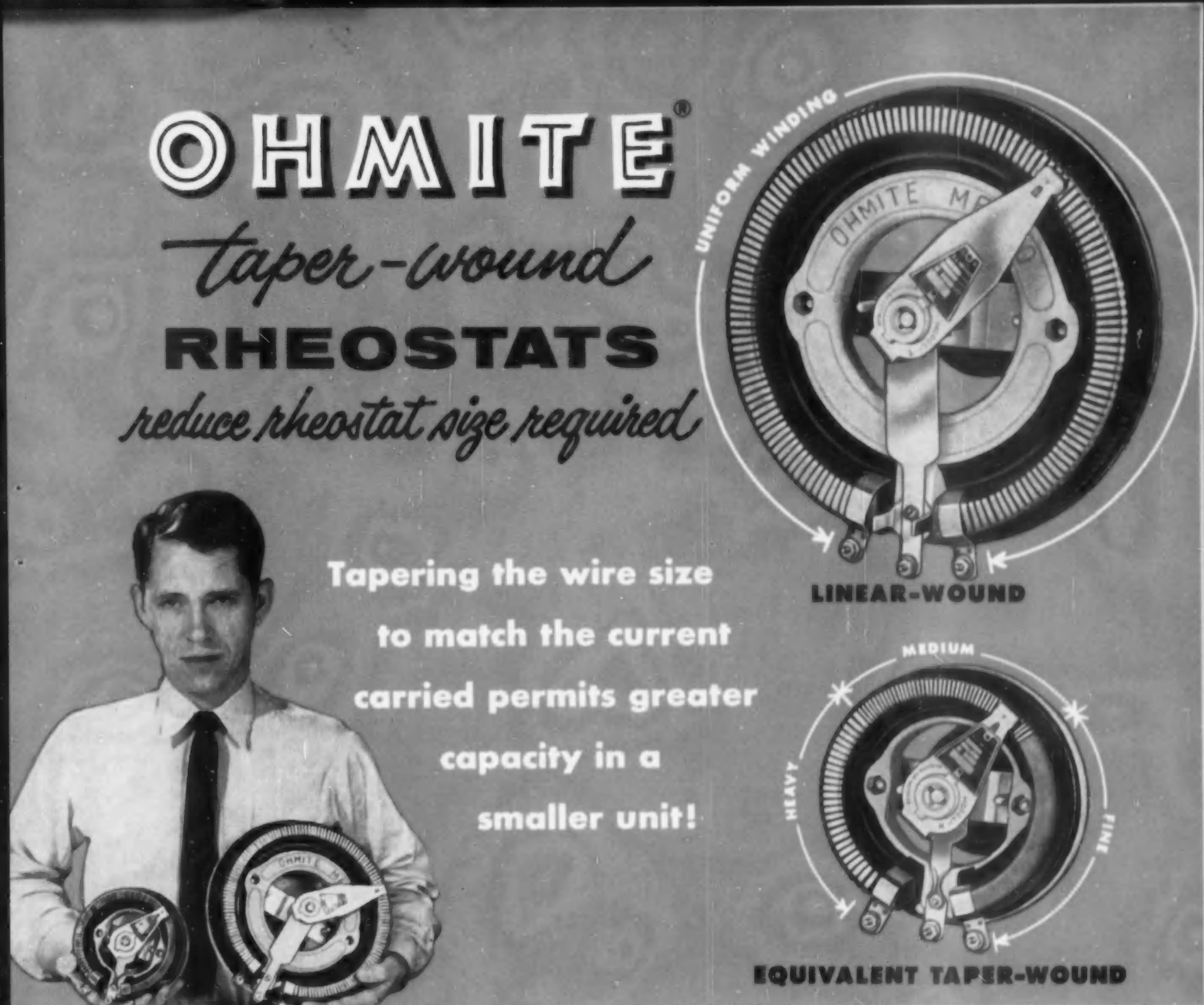
► **Elgin National Watch Co.**, which has made frequent forays into the electronics field during the past two years in a move to diversify operations, has herded these acquisitions into a new **Micronics Div.** Granted a breather from government procurement of ammunition components and bolstered by President J. G. Shannon's declaration that opportunities for watch-precision miniaturization are "virtually unlimited", Elgin has assigned the division a three-year sales goal of $25 million. Functions and personnel of the company's **Ordnance Div.** are being channeled into Micronics, which is headed by George W. Fraker, former chief of Ordnance. At the same time Elgin has pulled the wraps off a few of its developments in military miniaturization. Among them: a high-voltage power-supply unit whose weight can be measured in ounces; a pulse generator 10 per cent the size of an earlier model and 75 per cent as expensive; and a detecting element whose cost is less than one per cent, size 50 per cent of estimate.

► A 50-kw nuclear research reactor, the first reactor earmarked for the Far East, will be built at Japan's Atomic Energy Research Institute, Tokyo, by **North American Aviation's Atomics International Div.** A contract between the American company and AERI calls for completion of the reactor within a year. It will be used for studies in botany, biology, agriculture, materials research, radioisotope production, etc. Cost: $250,000.

► **Simpson Electric Co.**, producer of electronic testing instruments, has formed an **Avionics Div.** to handle what for Simpson is a new line: aircraft components. Under Dudley Hansen, the division is at work on its first volume order: a range-finder said to be the first to incorporate the D'Arsonval self-shielding core-movement magnet.

► Two new divisions have joined **Perkin-Elmer's Vernistat Div.** in special-purpose work (Vernistat has been turning out potentiometer-type devices for servo systems and analog computers since 1954). "An anticipated growth in their respective fields" was the reason given by President Richard S. Perkin for establishment of the **Instrument Div.** (development, production, and sale of laboratory

(*Business news continues on p. 174*)



A smaller rheostat may often be used for a given load by having the rheostat windings tapered or wound in two or more sections of diminishing wire sizes. This can be done because only the first turn of the winding carries the maximum current . . . succeeding turns carry reduced amounts. This makes possible great savings in control-panel space, making Ohmite taper-wound rheostats particularly useful in portable equipment. Ohmite taper-wound rheostats are also very durable because they use the largest wire sizes practical for the current to be carried.

MORE UNIFORM CONTROL—For a given application, the tapered winding also provides more uniform control. Because a linear-wound rheostat adds a constant number of ohms per degree of rotation to a constantly increasing number of ohms, the current changes more slowly as the resistance is increased. A tapered winding, by increasing the number of ohms per degree of rotation as the total ohms in circuit increases, makes the current curve more nearly linear.

Ohmite has an extensive line of standard tapered rheostats, or will design special tapered windings to suit individual needs.

Write on company letterhead for Catalog and Engineering Manual No. 40.

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WHAT'S NEW

Important Moves by Key People

▶ In need of a general manager for its new San Jose, Calif., plant (CtE, April, p. 35), IBM found one at its Kingston, N. Y., Military Products Center. But the transfer to the coast of Kingston General Manager **Gavin A. Cullen** made several changes mandatory in the upstate New York community. Among the new appointments there are these: **Robert P. Crago,** formerly assistant general manager, to general manager, succeeding Cullen; **Richard J. Whalen,** formerly manager of engineering, to assistant general manager, and **Harold D. Ross,** formerly manager of development engineering, to manager of engineering. Cullen, who joined IBM at Endicott, N. Y., in 1932, will direct both manufacturing and production engineering activities at San Jose. Crago, who started in 1949 at Poughkeepsie, N. Y., led a computer project there in March 1955. Whalen and Ross joined IBM in 1949, the first at Poughkeepsie, the other at Endicott.

▶ **Joseph T. Johnston,** formerly director of quality control for Consolidated Electrodynamics Corp., has advanced to top consultant in a guided missile instrumentation group. Taking the position left vacant by Johnston is **Ahlert P. Stuhrman,** who comes to Consolidated from Convair-Pomona, where he has been manager of quality control. Before joining Consolidated in 1954, Johnston was with General Electric Co. and Convair-Pomona. Stuhrman served as director of engineering for Electrotechnic Corp., as vice-president and chief engineer of Wilcox Electric Co., and with Eastern Air Lines and Pan American Airways before going with Convair three years ago.

▶ Motorola, Inc., has made two appointments in its Semiconductor Products Div. **Dr. William E. Taylor,** formerly senior project leader of materials research, becomes chief engineer of the Materials Research Dept., and **Dr. W. R. Sittner,** most recently with Hughes Aircraft Co. and Pacific Semiconductors, Inc., becomes associate director of the division's research and development. Taylor, who has been a metallurgist in the Oak Ridge National Laboratory, joined Motorola's semiconductor program at its inception in 1952. Sittner has had additional experience with Bell Telephone Laboratories.

▶ **John T. Reid,** the new research

H. D. Ross

J. T. Johnston

W. E. Taylor

J. T. Reid

A. O. Black

R. S. Medlock

manager of ASME, has been on the society's staff since 1951. Before that he was with Westinghouse Electric Corp. at Newark, N. J., and the Lock Joint Pipe Co. of East Orange, N. J.

▶ New president of Magnetics, Inc., is **Arthur O. Black,** a founder of the company and former executive vice-president and director of sales. **William D. Dickey** is the new executive vice-president. Black served several years on the developmental engineering staff of the Naval Ordnance Laboratories. Dickey, who will also be general manager for production, was with H. K. Porter Co. before joining Magnetics last year.

▶ **Reginald S. Medlock,** who heads the Research & Development Dept. of George Kent, Ltd., Bedfordshire, England, has been appointed to Kent's board. He recently chairmanned the Control Section of the Society of Instrument Technology (England).

▶ The new director of flight test operations for Ramo-Wooldridge's Guided Missile Research Div. is **Dr. John Sterner,** a former vice-president of Baird Associates, Inc. He helped found Baird after serving for four years in the Army Ordnance Corps' metallurgical research laboratory at the Watertown, Mass., Arsenal. He will direct his division's operations at Patrick AFB, Florida.

▶ As chief of the Solid State Physics Section of the National Bureau of Standards' Atomic & Radiation Physics Div., **Dr. Hans P. R. Frederikse** will direct research on electrical, optical, thermal, and mechanical properties of intermetallic semiconductors and grey tin. Frederikse, a native of The Netherlands, lectured in the Physics Dept. of Purdue University before coming to the bureau in 1953.

▶ **S. Albert Lazoni,** formerly chief engineer in the Cathode Ray Tube Div. of National Union Electric Corp., has been named assistant to the president of Decker Aviation Corp. In his assigned area of engineering, research, and development, Lazoni will deal primarily with rocket and satellite instrumentation.

▶ With **William J. Katt's** transfer to the automatic process control group of Monsanto Chemical's Research & Engineering Div., **Frederick W. Enoch** moves up to manager of the electrical and instrumentation section of the Organic Chemicals Div., the spot vacated by Katt. Both appointments are in the company's Engineering Dept. Katt joined Monsanto in 1947. Enoch, most recently a group

leader at Monsanto, Ill., joined in 1940.

► **Vernon B. Benfer,** appointed general manager of the Aircraft Engineering Div. of Lear, Inc., has been staff assistant to the president for the past three years. He joined Lear in 1950, after experience with Lockheed Aircraft Corp., the Glenn L. Martin Co., and the Aeromatic Propeller Div. of Koppers Co.

► **John E. McBrian,** who joins the development engineering staff of North Electric Co. as senior electronics project engineer, has done electronics work with the National Broadcasting Co. and L. M. Ericsson Co. of Stockholm, Sweden.

► Another man who stayed with the Precision Potentiometer Div. when Electro Circuits, Inc., sold it to General Controls Co. (CtE, May, p. 28) has been raised by GCC. He is **E. Edwin McKinney,** who becomes field engineer for PPD at Burbank, Calif.

► **Frank H. Squires,** the new director of quality control for Topp Industries, Inc., has held similar posts with Lear, Inc., Hughes Aircraft Co., Air Associates, Inc., and Thomas A. Edison Industries. He is chairman of the Los Angeles section of the American Society for Quality Control.

► **Sidney Kasindorf,** who in 1924 miniaturized the five-tube radio to the smallest size then known, has been named director of product engineering for TelAutograph Corp.'s TelAutograph Div. He has done communications work with Packard-Bell Co., Federal Telecommunications Laboratories, and Hillyer Instrument Co.

► U. S. Testing Co. has added **Dr. Charles W. Vickery,** formerly mathematical consultant to Fairchild Engine & Airplane Corp. and Republic Aviation Corp., to the research staff of its main laboratories in Hoboken, N. J. He will do experimental work in electronic component testing. Before entering the aviation field, he did operations analyses for the Naval Ordnance Test Station in California.

Control Engineer Pens a Few Notes on Music Appreciation

A headline-writer friend of ours can't help taking his foot off the gas when he passes a billboard and counting the letters in the message. You'd think another acquaintance, a lighting expert, is an art connoisseur, the way he pulls up short in front of every painting he sees, but he's just inter-

Bendix General Purpose Computers are saving users untold years of engineering time. This **time-saved** factor, as in the cam designs described here, is the common denominator which makes the Bendix Computer so effective in every line of work where complex mathematical problems must be solved.

PROBLEM: To design 14 cams for control mechanisms. The radii (approximately 1400) of each cam were to be computed at even ¼° points with the radii accurate to the nearest ten thousandths of an inch.

CONCLUSION: (Directly quoted from the Bendix user) "Figuring conservatively, several hundreds of thousands of equations were solved in the 40 hours needed to run the cams on the Bendix G-15 Computer. It has been estimated that it would take an engineer about three years to do the same work and possibly a fourth year to find his mistakes. Computing with the G-15 not only cut the cost of the task; but, often more important, freed engineers for other work and enabled us to get the units on the market ahead of competitors."

The Bendix G-15 is a high speed, large capacity digital computer. Because of its low cost, users have found that the Bendix Computer can be written off in 3 years or less with the savings it can effect.

Bendix Computer

Bendix Computer Division, Bendix Aviation Corp.
5630 Arbor Vitae Street, Los Angeles 45, Calif.

Tell us how we can economically use the Bendix Computer in our engineering, research and control functions.

Name________________ Title________________

Company________________ Address________________

ested in the way the picture is illuminated. We think there's something very quaint and human about these quirks, and we feel a certain affection for the gentlemen who possess them. So it's no wonder we were captivated by the reactions of one control engineer who attended a recent symphony concert. This fellow, who came to our attention via *Personnel Administration* magazine, seems a likely candidate for our list.

Apparently absorbed in thoughts about miniaturization, conservation of equipment, overshoot, step-input, and the like, the engineer took his seat in the concert hall and proceeded to listen. He returned to his laboratory several hours later and entered the following remarks in his notebook:

"For considerable periods the oboe players had nothing to do. The number should be reduced, and the work spread out more evenly over the whole of the concert, thus eliminating peaks of activity.

"It was noted that all twelve first violins were playing identical notes. This seems unnecessary duplication: the staff of that section should be drastically cut. If a large volume of sound is required, it could be obtained by means of electronic-amplifier apparatus.

"Much effort was absorbed in the playing of sixteenth and so-called 'grace-notes'. This is an excessive refinement. It is recommended that all notes should be rounded out to the nearest eighth note. If this were done, it would be possible to use trainee and lower-grade operatives more exclusively.

"There is too much repetition of some musical passages. Scores should be drastically pruned. No useful purpose is served by repeating on horns and wood-winds a passage which has already been adequately handled by the strings. It is also estimated that if all redundant passages were eliminated the whole concert time could be reduced to twenty minutes, and there would be no need for an interval or intermission.

"The conductor concurs generally with these recommendations, but expresses the opinion that there might be some falling-off in box office receipts. In that unlikely event, it should be possible to close sections of the auditorium entirely, with a consequent savings in overhead, lighting, janitor service, heating, etc."

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*600 RPM Operation

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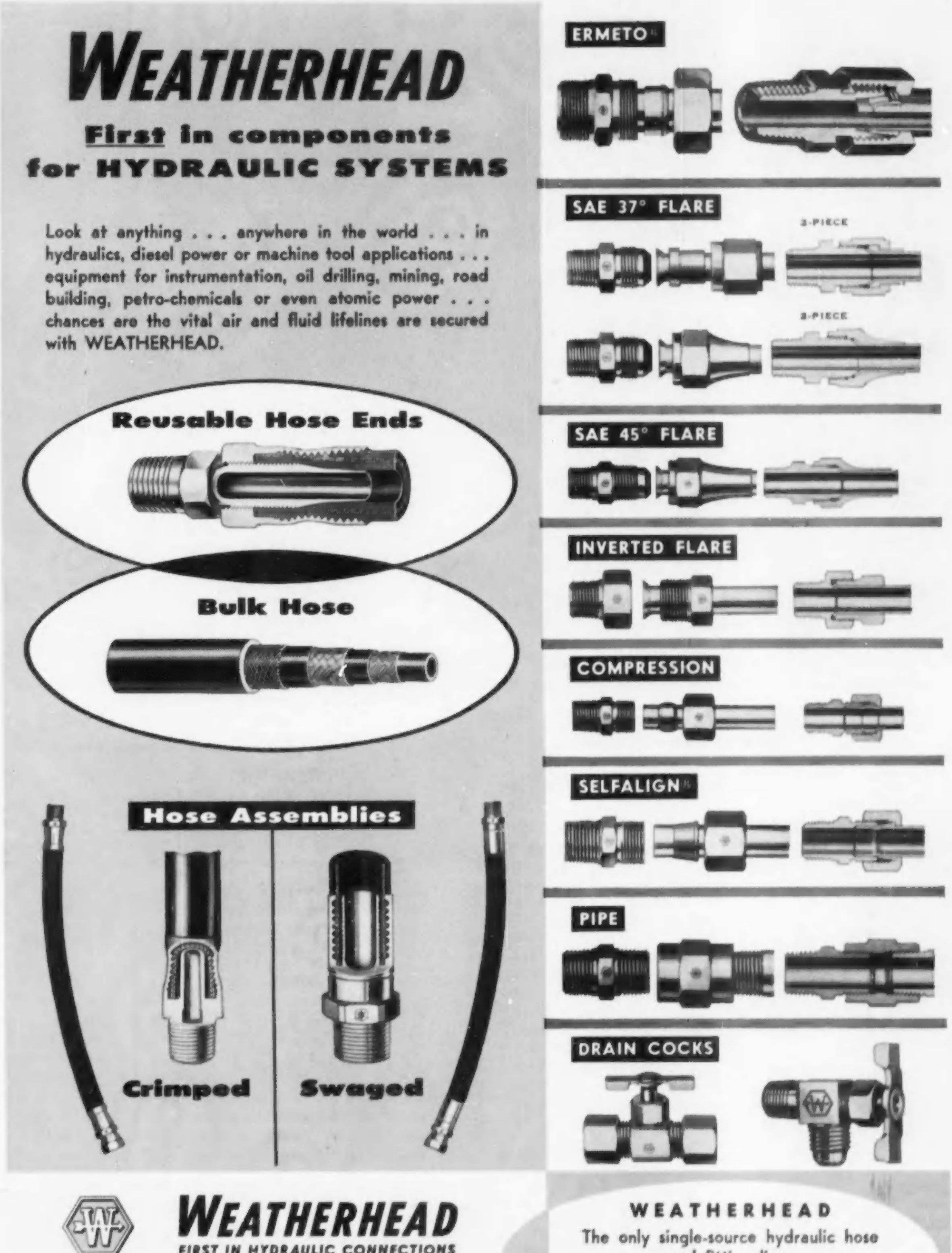
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Indicator

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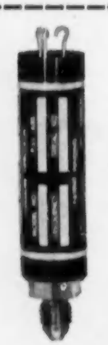
1 Indicates measurement signals from remote Vibrotron digital sensing gages directly in numbers.

2 Pressure, temperature or flow measurements are indicated directly in absolute or percent full scale numbers.

3 Visual read-out is provided from 000 to 999 in steps of 0.1 for a percentage type indication allowing maximum utilization of digits.

4 May be used with printer or electric typewriter for permanent digital recording.

5 Supplementary memory feature . . . see below.



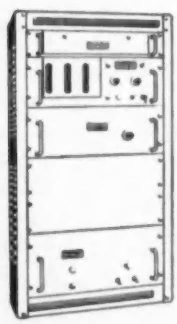
BJ VIBROTRON DIGITAL GAGE

The heart of BJ digital systems is the patented Vibrotron gage. This electronic sensing device utilizes a vibrating wire which is tuned by an element sensitive to pressure, temperature or flow. The Vibrotron gage generates its own precision measurement frequency signals which can be transmitted by radio link or direct wire without loss of accuracy.

BJ MEMORY FILE

This companion unit allows the BJ Digital Indicator read-out to be set to any desired base number (such as 000) . . . and retains this base as a digital constant.

Make your systems count! This new P-T-F Digital Indicator is one of a group of BJ digital systems building blocks engineered to indicate, record and control pressure, temperature or flow operations.



The P-T-F Digital Indicator and its auxiliary Memory File are designed for standard relay rack mount or can be individually cased.

For full information on these and other new BJ-Borg-Warner products, write for the special technical file "Make Your Systems Count."

BJ ELECTRONICS

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A major step forward has been achieved by uniting Fairchild precision potentiometers with dynamically balanced and sensitive pressure-sensing elements. The result is a line of superior pressure transducers with potentiometer outputs and featuring all the characteristics of precision, reliability and quality that are identified with Fairchild potentiometers. A specially trained staff of engineers is at your service to consider problems of transducer design and manufacture to meet your specific requirements.

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Featuring Fairchild accuracy and reliability

The TP-200 illustrated is a new and smaller addition to the line of Fairchild Transducers. These components are now available in a wider range of resistances in either linear or functional, single or dual potentiometer output elements. Measuring only approximately 2″ by 2″, the TP-200 features a single pressure sensitive diaphragm element which actuates one or two precision potentiometers through dynamically-balanced, stable mechanical linkage. It features unitized construction for easy assembly, field calibration and repair. Variations of size, conformation, and pressure ranges for measurement of differential, absolute, or gauge pressures are available. For complete information write Fairchild Controls Corp., Components Division, Dept. 140-77C.

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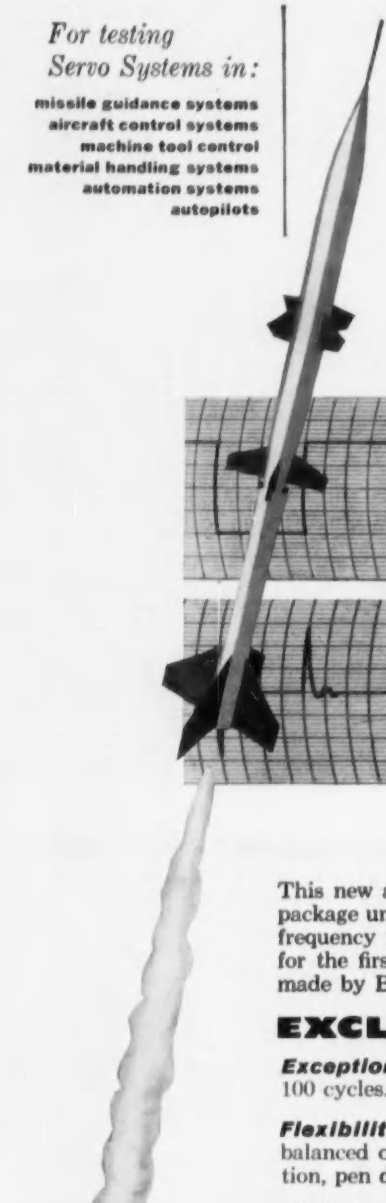
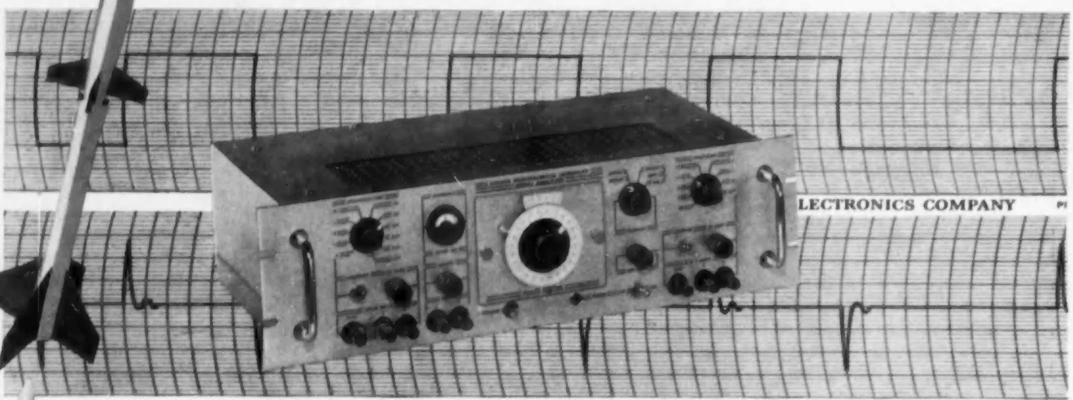
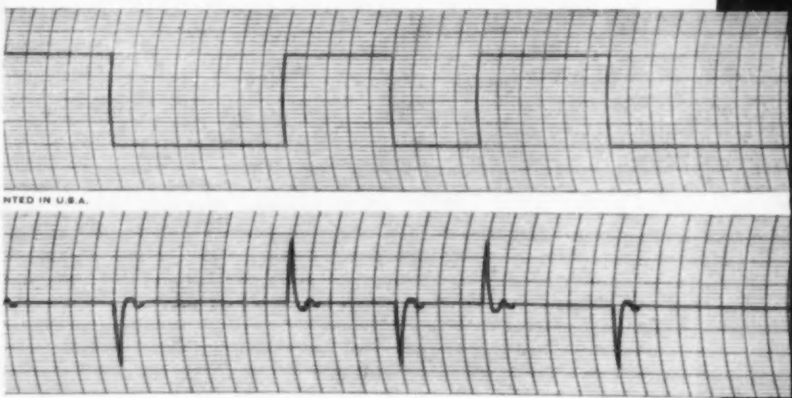



LECTRONICS COMPANY

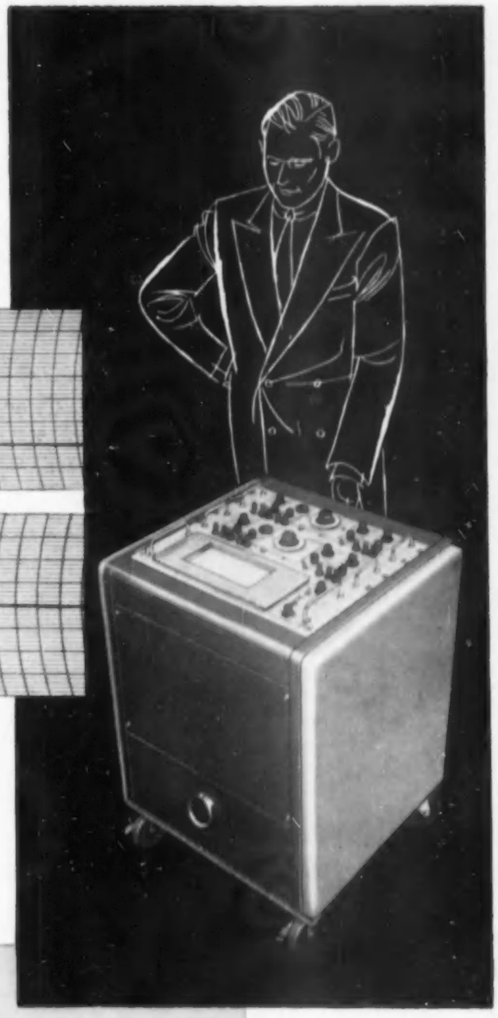
in test instrumentation...then we designed the

Brush

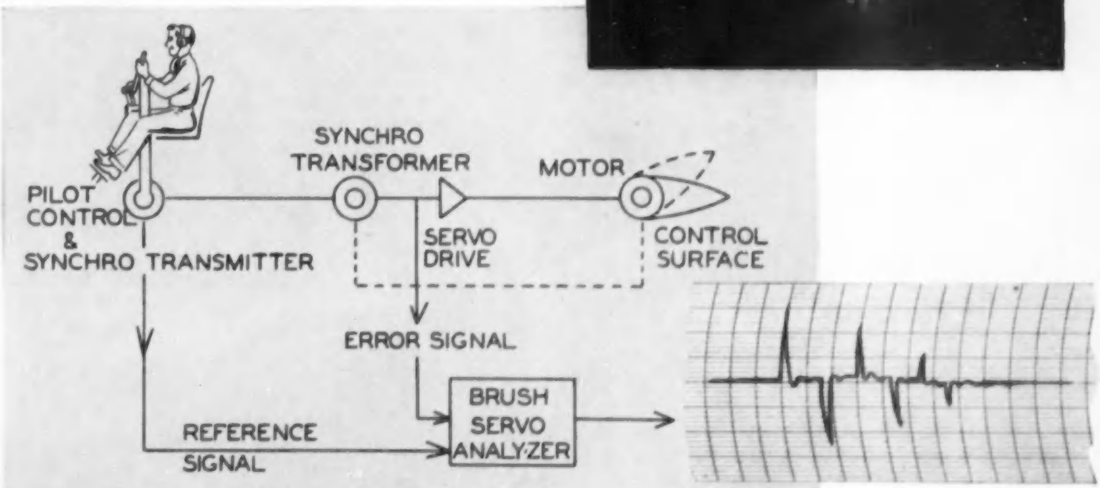
AMPLIFIER



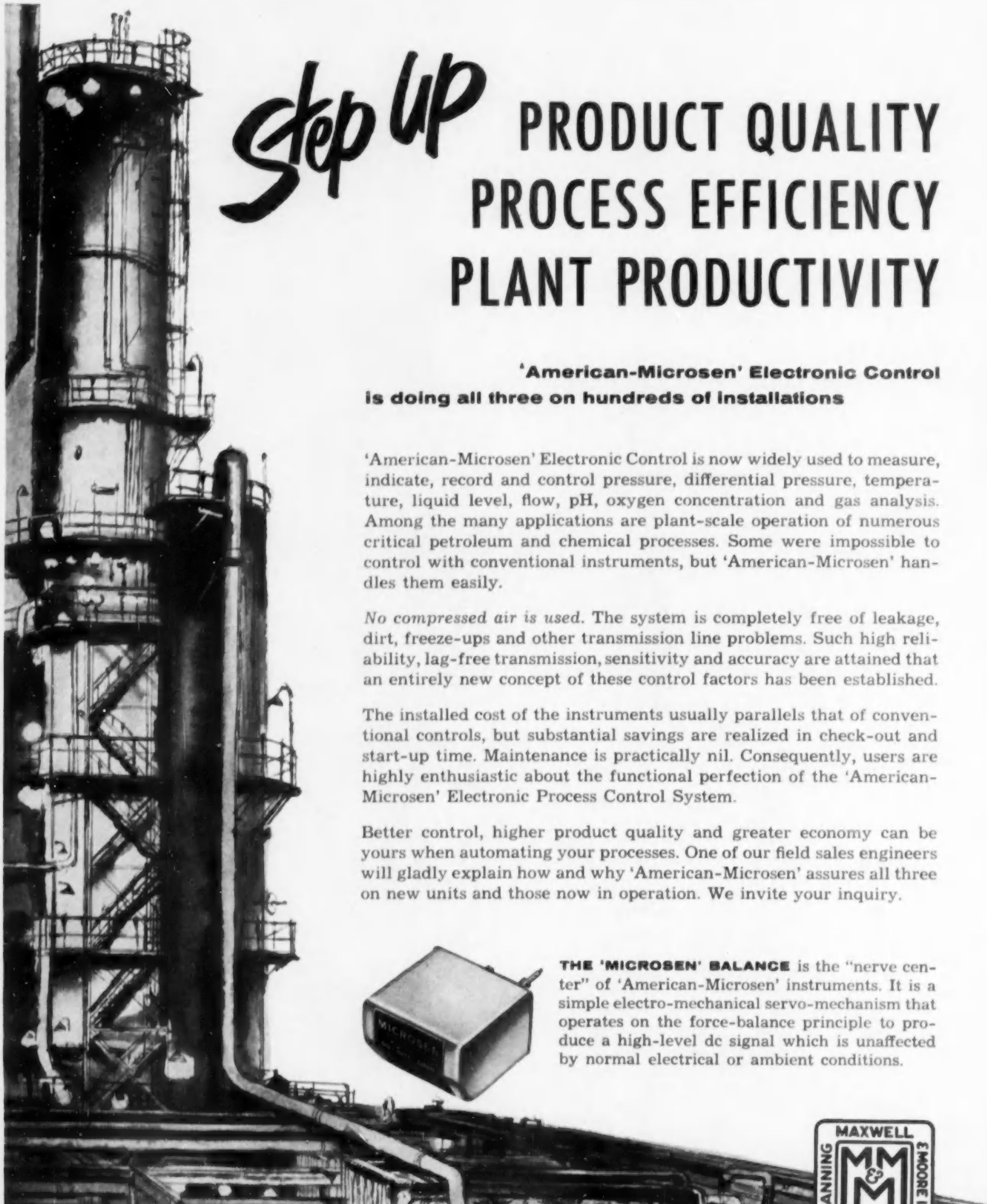
▲ Two channel recording of test of servo control system. Up to six channels of information can be recorded if desired.



Mobile instrument cart carries complete gear ▶ for servo testing, consists of two amplifiers and dual channel oscillograph. Equipment can also be mounted in racks or consoles.



Checking error signal on typical aircraft control system with the Brush Analyzer System.



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'American-Microsen' Electronic Control is doing all three on hundreds of installations

'American-Microsen' Electronic Control is now widely used to measure, indicate, record and control pressure, differential pressure, temperature, liquid level, flow, pH, oxygen concentration and gas analysis. Among the many applications are plant-scale operation of numerous critical petroleum and chemical processes. Some were impossible to control with conventional instruments, but 'American-Microsen' handles them easily.

No compressed air is used. The system is completely free of leakage, dirt, freeze-ups and other transmission line problems. Such high reliability, lag-free transmission, sensitivity and accuracy are attained that an entirely new concept of these control factors has been established.

The installed cost of the instruments usually parallels that of conventional controls, but substantial savings are realized in check-out and start-up time. Maintenance is practically nil. Consequently, users are highly enthusiastic about the functional perfection of the 'American-Microsen' Electronic Process Control System.

Better control, higher product quality and greater economy can be yours when automating your processes. One of our field sales engineers will gladly explain how and why 'American-Microsen' assures all three on new units and those now in operation. We invite your inquiry.

THE 'MICROSEN' BALANCE is the "nerve center" of 'American-Microsen' instruments. It is a simple electro-mechanical servo-mechanism that operates on the force-balance principle to produce a high-level dc signal which is unaffected by normal electrical or ambient conditions.

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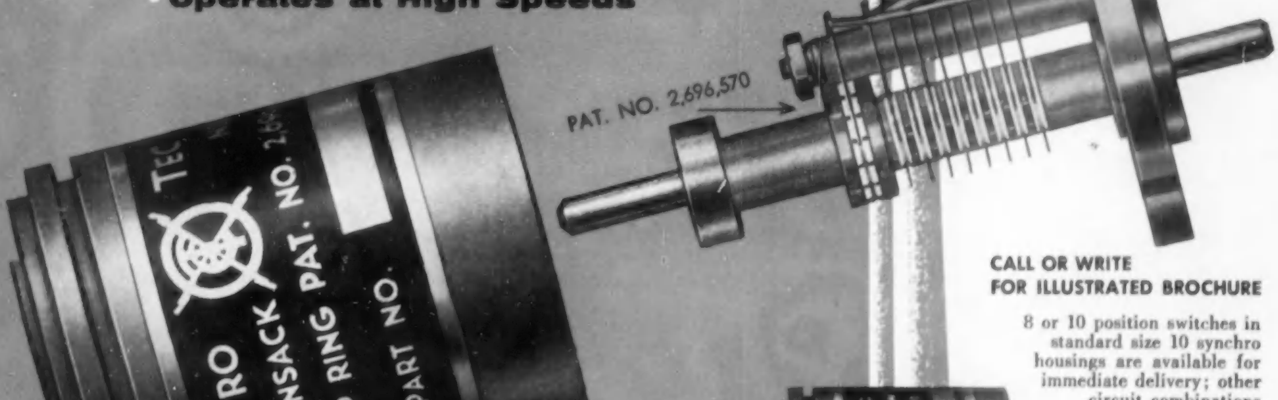

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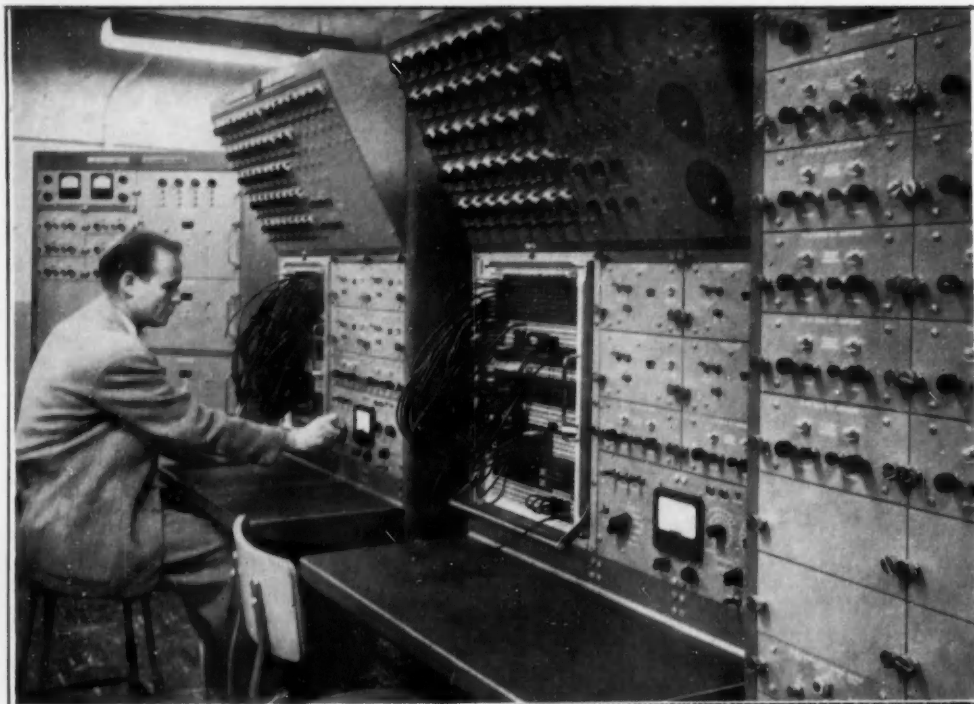
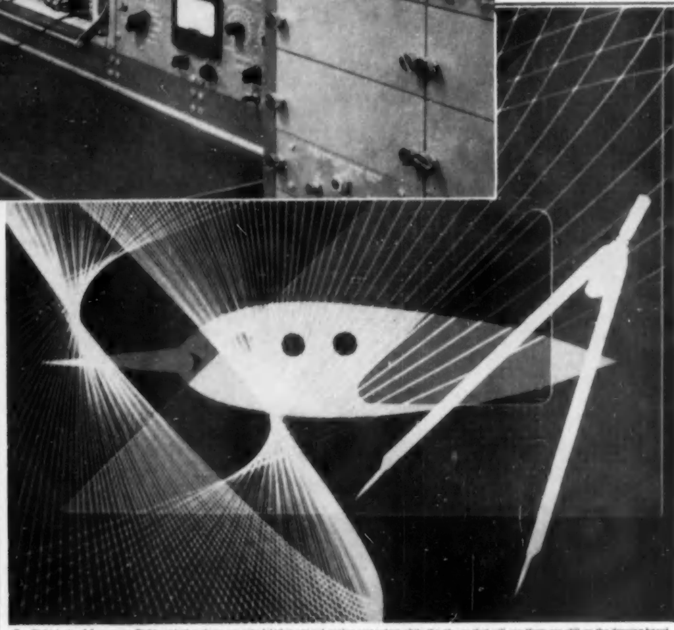


Trust PACE for Progress . . .

North American Aviation, Inc.

A flip of the operating console switch by advanced Mathematician John R. Chapin starts operation of Electronic Associates' Precision Analogue Computing Equipment (PACE) in the Computer Room of Autonetics, a division of North American Aviation, Inc. PACE Equipment is employed here to determine both design parameters and refinements of an aircraft's advanced, radar—equipped fire control system. One more example of PACE Equipment serving progress in major industries. Complete details on the flexibility and the reliability of PACE Analogue Computing Equipment will be forwarded to you immediately. We will also gladly furnish you with information on the rental of time and computing systems at the Electronic Associates' Computation Center in Princeton, New Jersey. Just write department CE-6, Electronic Associates, Long Branch, New Jersey.



Pre-flight tests of Autonetics flight control systems are simulated in special analog computers while the planes that will use them are still on the drawing board.

Now man can fly a plane before it's built

For many years there were problems in the design of aircraft which could not be solved practically except by trial and error—a slow, costly, often dangerous method.

Today much of this guesswork and time, as well as some of the hazard, has been eliminated—thanks to newly designed electronic devices. Now specially designed computer systems simulate on the ground actual conditions of supersonic flight...help predict the performance of aircraft which are still on the drawing board.

Although actual flight will always be the final test of any aircraft, these special uses of computer systems by the AUTONETICS Division of North American Aviation are daily helping solve complex problems in less time and with more certainty than ever before ...speeding scientific break-throughs in the whole intricate field of advanced electro-mechanical systems—auto pilots, auto navigators, automatic armament controls, and other automatic control systems.

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A Control Reporter Views Yankee Machining

(Senior Associate Editor Byron Ledgerwood is closely following the rapid growth of control technology in the machine tool field. Below are By's observations—extracted from a recent Trip Report—on progress among the New England tool makers.)

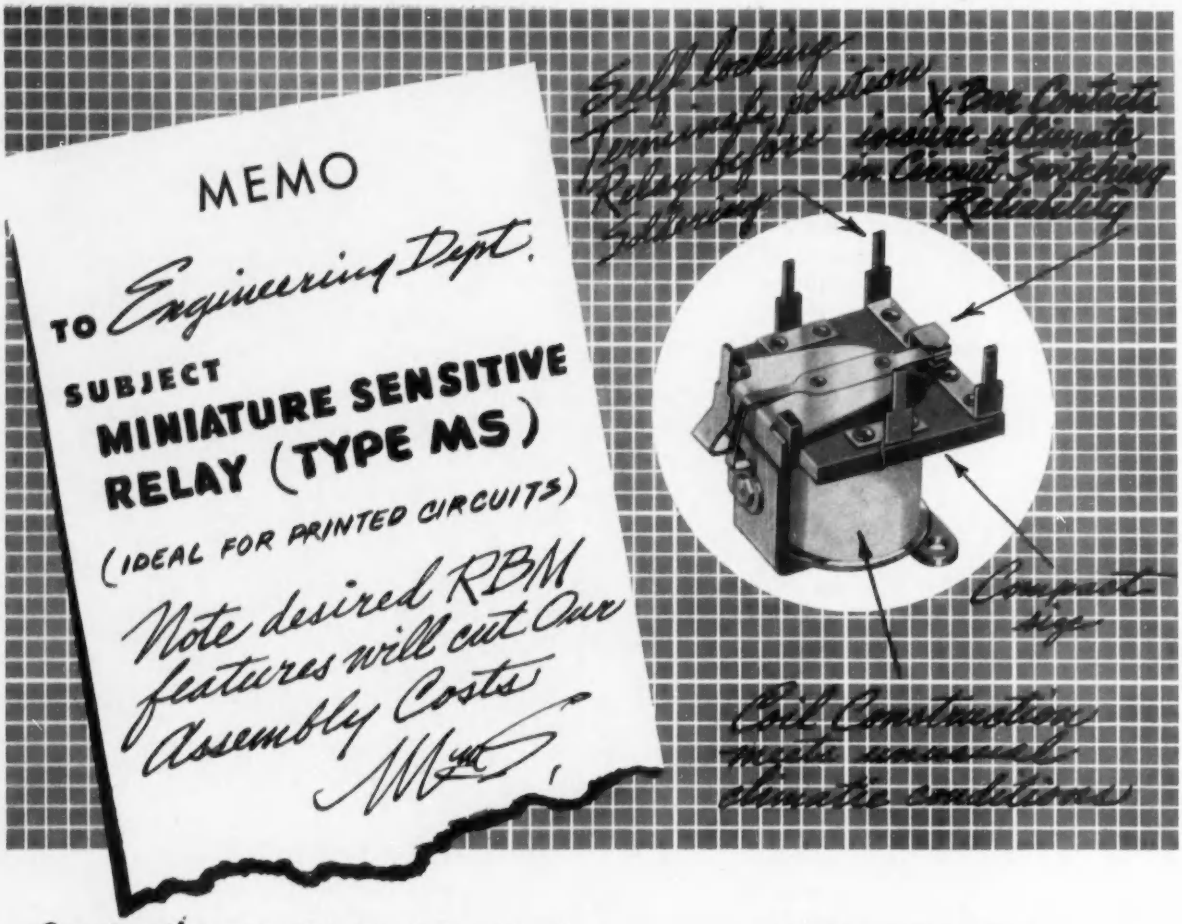
Some original thinking at Pratt & Whitney

"On the way up north I stopped off for a rewarding visit with J. J. Jaeger, Chief Engineer of the Machinery Div. of Pratt & Whitney in Hartford. Jaeger has an interesting background. He took his graduate work at MIT at the same time as Gordon Brown, has a well-rounded knowledge of automatic control theory. At present he has two servo men working for him and is looking for at least one more. Jaeger's ideas on continuous machine tool control conflict with others in this field. To begin with, all the complex digital systems program and control tool-center position. He feels there is a better approach for some types of machines. Cooperating with another firm, he has developed an arrangement which compensates for tool size between the output of a normal numerical director and the tool-position-control system. Secondly, he believes it is tough to predict the proper machining sequence for large, complex workpieces—yet the big selling point for these systems is that one or two pieces can be economically turned out through straightforward programming. He quoted a simple contour-following job in which the first piece took 90 hours to machine, this being cut to 32 hours after several pieces were run. Jaeger feels that such a learning period is usually necessary, and that people are trying to build control systems much more accurate than the machines they are controlling. This seems a realistic attitude and I hope to get him to elaborate on it in an article.

CYPAK is being tested

"Two other interesting points at P&W. At the moment they are offering digital control to permit point-to-point positioning for linear and angular jigbore operations. They are also actively considering CYPAK components (see *New Products*, p. 125) in their new control circuits. A Westinghouse experimental CYPAK panel was being used in the lab and apparently four or five of these have also been farmed out to customers.

"A morning in Worcester to chat with A. G. Sangster, Chief Engineer of Arter Grinding Machine Co. This firm has been perfecting its table-positioning system for the last three years. The table is punch-tape-programmed and driven by a constant-speed ac motor on each axis through Warner clutches and gear-



Construction—Printed circuit terminals are designed with snap-in feature which holds relay in printed circuit board without lugging prior to solder dip.

Other versions of MS relay available with standard solder type terminals and insulating base, where required. Also with 4 N.O. isolated circuits having common make.

While not yet in production, extra-sensitive version has been developed. Maximum coil resistance 18,000 ohms, nominal sensitivity .030 watt, maximum sensitivity .020 watt, overall height 1-9/16". All other details same as standard MS relay.

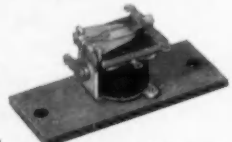
Application—Type MS is an ideal relay for any application requiring a compact, highly reliable single pole D. C. device, where a low cost solution is required because of volume usage and competitive problems.

The fact that industry has already used over a million units of this design is your assurance that the R-B-M Type MS relay will meet your most exacting requirements.

Contacts used in Type MS are of the cross bar type, which offer the ultimate in reliability throughout the life of the relay. Molded bobbin design has eliminated coil failure on sensitive applications under severe climatic conditions.

OTHER VERSIONS

SOLDER TERMINALS
4 isolated circuits with common make contact.



INSULATED BASE
Solder terminals mounted on insulating base.

EXTRA SENSITIVE VERSION

ENGINEERING DATA	
Specifications	Miniature Sensitive Relay Type MS
Contact Form	S. P. D. T.
Contact Rating	1 amp. 32 V.D.C. non-inductive
Coil Resistance	Up to 10,000 ohms
Nominal Sensitivity (Coil Input)	.060 Watt
Maximum Sensitivity	.040 Watt
Approx. Dimensions	1-1/8 x 1-1/16 x 1-1/32"

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ing. It uses a simple coded printed-circuit digital-position-sensing device and always positions from one direction so that backlash is no problem. The setup sells for $16,000 for two axes and they are readying five for delivery in the near future. Arter hardly expected the great interest it created at the Machine Tool Show and only wishes it had far more funds to create the modifications requested by at least a dozen people for special applications.

Buyer interest catalyzes action

"Stopped off at Machinery Electrification, Inc., in Northboro, Mass., and had a brief session with F. P. Dunigan, engineering VP. Dunigan did the electronic work on Arter Grinding's positioning table. His outfit does special machine control work of the sequence variety, although it is presently getting into closed-loop systems. They did all of the electronic work on the Arter Jigmatic and are now deep into a continuous control system for an unidentified firm. The company has a special talent: a wide background in techniques for load control of manufacturing machinery (flour, sugar, etc.) as well as machine tools.

"On up to the Machine Tool City—Springfield, Vt. Almost 90 per cent of the employable people in this thriving town of 15,000 work for three machine tool companies and there seems to be considerable engineering cooperation between the various engineering departments. For example, five years ago they ran a night course on digital computers for five engineers from each of the three firms, and are presently considering an updated computer clinic as well as a course in automatic control theory.

"P. C. Durland, Chief Engineer of Bryant Chucker Grinder Co., gave me a rundown on company developments. This firm makes internal grinders and has the problem of controlling hole size. For low-accuracy operations (0.0005 in.) grinding-wheel size is controlled on the finished workpiece by facing with a diamond. For more accuracy, hole size is checked using block sizing with diamond dressing for the rough cut (the block and grinding wheel oscillate together, with the block entering the hole as the wheel leaves it). For high accuracy, pneumatic gaging is used in a similar oscillating arrangement. In conjunction with pneumatic gaging they have developed a line of simple statistical computers which they call Bryant Process Controllers (note the use of the word 'process' for a grinding operation). This is similar to the system described in the last Kliever article (CtE, Nov. '55, p. 77) and to the lathe control systems developed by Jones & Lamson and Sunstrand.

A "process control" system for grinding

"Over at Fellows Gear Shaper Co. I checked in on progress in the gear-size-gaging and cutter-positioning system this com-

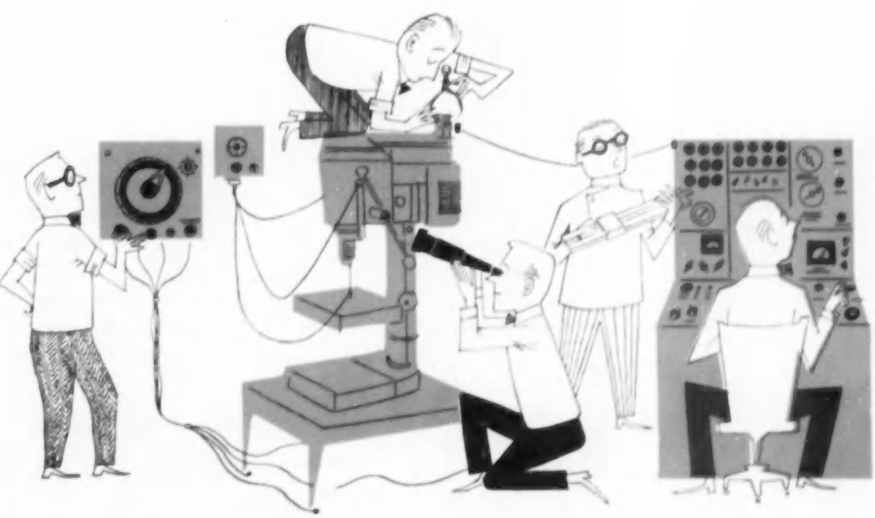
pany exhibited at the Machine Tool Show. Surprisingly, the project has been dropped. Neal Cobb, Chief Engineer, told me that nobody seemed to want to buy it and, furthermore, that they found that when a shaping cutter is worn enough to require readjustment, it no longer cuts properly shaped teeth. A corollary seems to be that if a machine tool requires a specially shaped tool, continuous reset gaging is useless since variations in tool contour will change workpiece contour. One new note at Fellows: it has just purchased a Bendix G15A computer for calculating cutter contour.

Sometimes gaging is superfluous

"Finally checked in with Dave Smith, Manager of Research at Jones & Lamson. This firm is moving ahead fast in readying the Binotrol lathe-control system (CtE, Sept. '55, p. 22) that attracted so much interest at the show last fall. It is currently redesigning some of the programming circuits and hydraulic servos and these improvements will be in the first half-dozen units already ordered for the field. J&L is also now deep into the design of a prototype numerical table-positioning system which will operate on somewhat the same scale as the GE system. It will use multispeed synchros to measure table position, but will be programmed by punched tape instead of punched cards. Dave mentioned that Farrand's linear Inductosyn seems to attract a good deal of attention in the machine tool control field. I gathered from him that Stromberg-Carlson is now unveiling a continuous cutting system which appears similar to Farrand's in that it is internally programmed to handle conic sections directly.

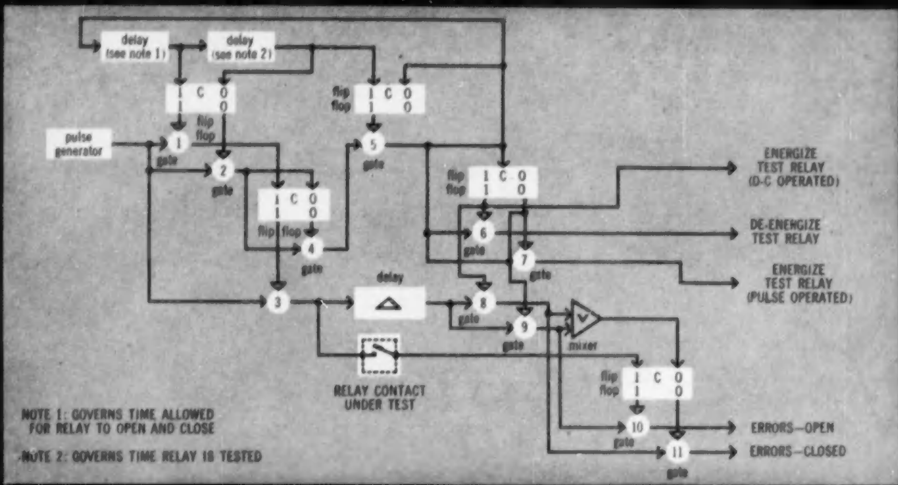
The machine tool field in ferment

"This trip through New England convinces me that the machine tool field is really changing. All the firms I visited had at least one qualified control engineer doing design work. Take Jones & Lamson alone: three out of its dozen research personnel are servo-trained. John Nichols (Project Engineer) had radar training during the war. And the company hired a PhD with digital computer background on March 1."



testing components with Burroughs pulse control systems

modern methods for testing relays



TOOLS FOR ENGINEERS

Small-signal sensitive relays, the backbone of many of today's high-speed computers, instruments, and other electronic devices, must meet exacting specifications of uniformity and performance. Until now, the testing of such relays has often been complicated by procedures which require time-consuming processing before results are known. This has generally reduced comprehensive testing to a sample basis rather than individual testing, a courageous procedure considering the possible down-time cost incurred by the equipment in which such relays are installed.

Burroughs Pulse Control Systems are minimizing this short-coming for leading relay manufacturers and users by providing a simple means of comprehensively testing each relay produced or purchased. Such factors as closing time, opening time, bounce, etc., are checked against a set of operating characteristics to a precise degree by digital methods which automatically indicate acceptance or rejection of the relay. When conditions require a change in relay operating characteristics, the Burroughs Testing System can be changed at will to meet new requirements.

Shown here is a typical example of how some of these manufacturers use a Burroughs Pulse Control System to test ultra-sensitive fast-acting relays. An interesting booklet describing relay testing in greater detail is yours for the asking. But if you have another component which you think can be tested better, faster, by digital techniques, just tell us about it. We'll be glad to work out a Pulse Control Testing System, at no cost, and show you how to avoid hours of engineering time and production headaches.

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Control
ENGINEERING

JUNE 1956

Standards Can Remove Roadblocks

Our mail, work with professional and trade associations, and our field pulse-takings pour forth information related in a usually random way to the subjects important to control engineering. But now and then, bits fall together into a correlation peak that demands our, and your, attention. We've watched current standardization activity come to just such a head from isolated pulses originating with groups active in machine tool control, industrial telemetering, and guided missiles.

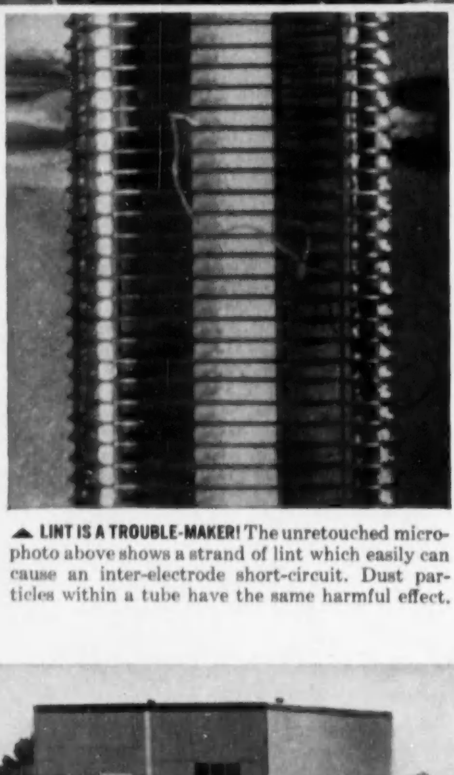
Pulse: The Aircraft Industries Association is surveying all manufacturers of numerically controlled millers and skin-mill continuous contouring machines to establish some basis for standardizing the data input to the power servos that actuate tables and cutting heads. Production flexibility in the event of all-out defense emergency is the objective. If the codes and metal-cutting axes were uniform, parts produced at one manufacturer's factory, or his vendor's factory, could be produced on automatic machines in other factories from telemetered or mailed tape-data.

Pulse: Telemetering equipment developed for testing missile flights in Florida and nuclear weapons at Operations Crossroads, Teahouse, and Greenhouse operates with speeds and accuracies orders of magnitude above normal commercial requirements. Some experts consider such high-speed telemetering applicable to industry, but point to a major roadblock: lack of standardization of coding, multiplexing forms, and required resolution. Standing committees of societies such as the American Institute of Electrical Engineers provide the block-crashing vehicle.

Pulse: The communication languages of machines and telemetering are not the only developments needing standardization in order to make progress. An engineer employed by the prime contractor to the Army Ordnance for the Redstone guided missile writes that types of drawings are just as important. He reports that one government agency's definitions of diagrams, schematics, and charts rarely agree with another agency's. However, there is an encouraging note: the American Standards Association now has Subcommittee Y14-15 on Electrical Diagrams hard at work on the problem.

Here are needs, briefly stated, that merit your attention. Don't look to others to meet them. If you have an interest, contact the associations mentioned and do your part. At least make known your point of view.

THE EDITORS



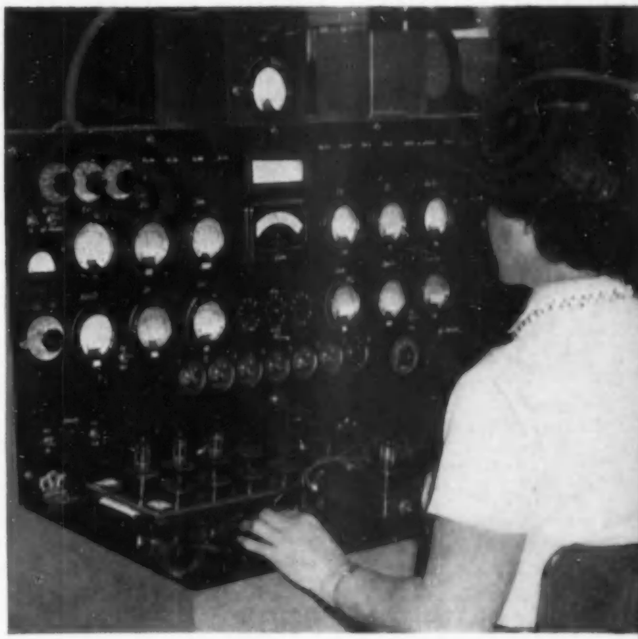
▲ **MANUFACTURED "UNDER GLASS"!** For optimum cleanliness, 6829's are assembled under glass-paneled protective hoods. All G-E employees who build 5-Star Tubes wear rubber finger cots, and their uniforms are lint-free Nylon and Dacron. These precautions are taken to ward off lint and dust, most frequent causes of intermittent tube "shorts".

FIRST GENERAL ELECTRIC HAS LINT-FREE

▲ **LINT IS A TROUBLE-MAKER!** The unretouched microphoto above shows a strand of lint which easily can cause an inter-electrode short-circuit. Dust particles within a tube have the same harmful effect.

▼ **1200 WORKERS ASSEMBLE 6829's AND OTHER HIGH-RELIABILITY TUBES** in this 5-Star building, located apart from the rest of G.E.'s Owensboro, Ky., tube factory. Because of the special white lintless uniforms, plus immaculately clean working conditions, "Operation Snow White" is aptly used to describe G-E 5-Star Tube manufacture. The entire assembly and inspection area is pressurized, with air that has been filtered, dehumidified and cooled.

▲ **SPECIALLY TESTED . . . BIASED TO CUT-OFF FOR LONG INTERVALS!** Life tests of G-E computer tubes under cut-off conditions, are made in order to be sure no "sleeping sickness", or failure to respond to grid input pulses, develops during inactivity. This is determined by means of periodic interface checks.



▲ **CHECKED FOR COMPUTER-SERVICE CHARACTERISTICS!** G-E computer tubes are specifically tested for those electrical qualities that closely affect tube operation in computer circuits. Among the characteristics checked are zero-bias plate current . . . cut-off performance . . . difference in cut-off between both triode sections.

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Shock-resistant design—comprehensive cut-off tests—further establish Type 6829 as the most trustworthy tube you can apply in military computers!

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Type 6829 has the many 5-Star design features that give added strength, such as a compact, sturdy tube cage . . . double mica spacers . . . a double-staked getter. In addition, tube assembly is carried on in immaculate surroundings free from lint and dust, while special tests assure those electrical qualities that are essential in achieving computer dependability.

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- ▲ **Permits viewing time-interval start and stop points on oscilloscope**
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BRIEF SPECIFICATIONS

FREQUENCY MEASUREMENT:	
Range:	10 cps to 1.1 MC
Accuracy:	± 1 count ± crystal stability
Input Minimum:	0.2 v RMS
Input Impedance:	Approx. 1 megohm, 30 μμf shunt
Gate Time:	0.001, 0.01, 0.1, 1, 10 seconds
Reads Directly In:	KC. Automatic decimal
PERIOD MEASUREMENT:	
Range:	0.00001 cps to 10 KC
Accuracy:	±0.3% (1 period); ±0.03% (10 periods)
Input Minimum:	1 v RMS
Input Impedance:	Approx. 1 megohm, 40 μμf shunt
Gate Time:	1 or 10 cycles of unknown
Standard Counting:	10 cps, 1 KC, 100 KC, 1 MC, External
Reads Directly In:	Sec, msec, μsec; automatic decimal
TIME INTERVAL MEASUREMENT:	
Range:	3.0 μsec to 100,000 sec (27.8 hrs)
Accuracy:	±1/ std. freq. counted ± stability
Input Minimum:	1 v peak. dc coupled
Input Impedance:	Approx. 1 megohm, 25 μμf shunt
Trigger Slope:	Pos. or neg. on start/stop independent or common channels
Trigger Amplitude:	−300 to +300 v adjustable
Standard Counting:	10 cps, 1 KC, 100 KC, 1 MC, External
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How to Set Three-Term Controllers

All too often the instrumentation of a process gets proper consideration only after the design of the process plant is well under way. This makes the selection and installation of the control system much more difficult. A better approach is to consider the process dynamics and the control system as two aspects of one problem that must be solved before the plant is constructed. This method allows much greater flexibility in plant design and controller selection. In any case, the control engineer must evaluate the entire control loop so that the best controller actions can be matched to the process. Last month, in "How to Find Controller Settings from Process Characteristics", Dr. Coon dealt with controllers having proportional, proportional plus reset, or proportional plus rate. Now she shows how to obtain three-term controller settings for difficult-to-control processes. These procedures apply both to installed processes and processes undergoing design.

GERALDINE A. COON, Taylor Instrument Cos.

Difficult processes require controllers combining all three actions: proportional, reset and rate. A proportional-plus-reset controller may not give satisfactory performance because the controlled variable deviates too much from the set-point or because the recovery time is too slow. Similarly, control with proportional-plus-rate actions may be unsatisfactory because the controlled variable shows too much offset. In these cases a three-term controller is needed.

THREE-TERM CONTROLLERS

Three-term controllers vary in design, but nearly all are complicated and limited by interaction of the reset and rate actions. However, results obtained under the assumption of noninteraction may often be applied, with proper interpretation, to interacting controllers.

Consider a noninteracting controller, that is, one with independent adjustments of sensitivity, reset rate, and rate time. The controller's transfer function is, therefore, $S(U/p + 1 + Tp)$, where S, U, and T are knob-settings:

S = proportional sensitivity (psi/in.)

U = reset rate (repeats/min)

T = rate time (min)

FIG. 1

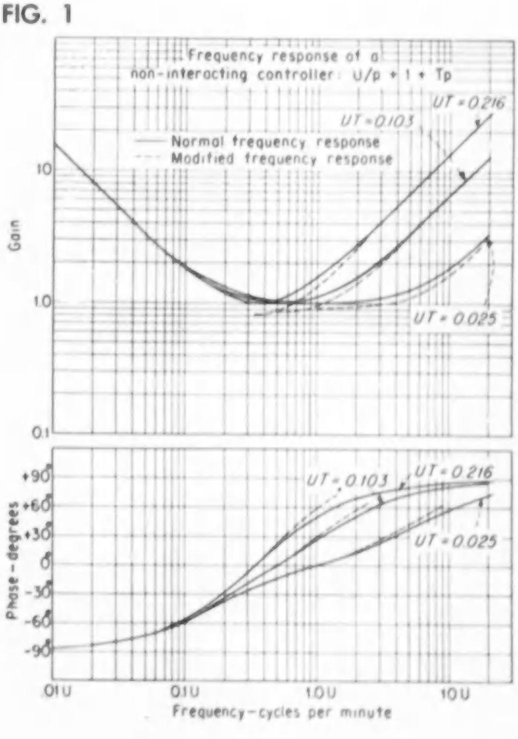


FIGURE 2

THREE-CAPACITY PROCESS

$T_1 = T_2 = T_3 = 1$ MIN.

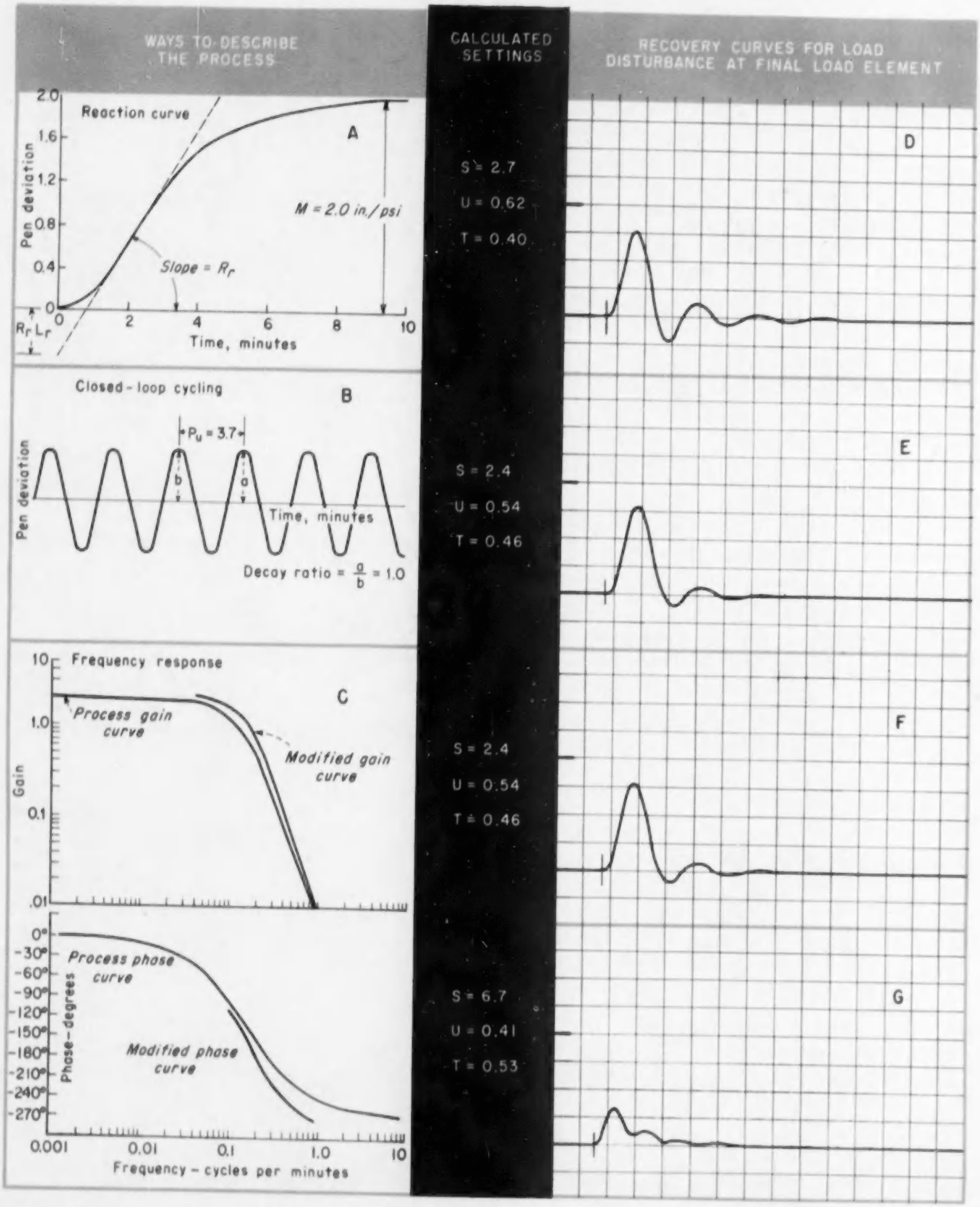


Figure 1 shows the response for this ideal controller at different values of UT that will be used in one of the methods for finding good settings.

Small deviations and fast recovery following a disturbance indicate good control. The procedures for finding good controller settings depend on the ways the process characteristics are described. These ways could be:

- a reaction curve
- continuous cycling of the closed loop
- frequency-response curves

A particular process has been investigated in these ways and the process description, computed settings, and resultant recovery curves, are compared in Figure 2. This process contains three equal noninteracting time constants of 1 min.

SETTINGS FROM THE REACTION CURVE

The reaction curve represents the process response to a unit step change in input under open-loop conditions. From this curve (Figure 2A), the reaction rate R_r and effective lag L_r are obtained by drawing a tangent to the steepest portion of the curve. These formulas, by Ziegler and Nichols, yield satisfactory control for many processes:

$$S = 1.2/R_rL_r \qquad U = 0.5/L_r \qquad T = 0.5\ L_r$$

Thus, L_r equals 0.80 min and the vertical intercept R_rL_r equals 0.44 in./psi. Therefore:

$$S = 1.2/0.44 = 2.7 \text{ psi/in.}$$
$$U = 0.5/0.8 = 0.62 \text{ repeats/min}$$
$$T = 0.5\,(0.8) = 0.40 \text{ min}$$

With the controller adjusted to these settings the controlled variable recovers from a sustained load change at the valve (final control element), as shown in Figure 2D.

SETTINGS FROM CLOSED-LOOP CYCLING

If the process can tolerate the disturbance caused by continuous oscillations, this technique can be used in the field to determine appropriate controller settings. Here the reset and rate actions are locked out of the controller; that is, reset rate and rate time both equal zero. Under closed-loop conditions a sufficient increase in proportional sensitivity results in continuous cycling, as shown in Figure 2B. This curve was obtained at an ultimate proportional sensitivity S_u equal to 4.0 psi/in. and the ultimate period P_u equals 3.7 min.

The quantities S_u and P_u describe the process, and from them the controller settings can be calculated in accordance with the following Ziegler-Nichols procedure:

$$S = 0.6\,S_u \qquad U = 2.0/P_u \qquad T = P_u/8$$

Thus, for the process in Figure 2B:

$$S = 0.6\,(4.0) = 2.4 \text{ psi/in.}$$
$$U = 2.0/3.7 = 0.54 \text{ repeats/min}$$
$$T = 3.7/8 = 0.46 \text{ min}$$

With the controller adjusted to these settings, the process, subjected to a load change, shows a recovery as indicated in Figure 2E.

SETTINGS FROM FREQUENCY-RESPONSE CURVES

Frequency-response curves also describe a process. These may be obtained by making experimental tests or calculations based on the process transfer function. In addition to its value in finding controller settings, frequency response aids analysis.

Continuous Cycling of the Closed Loop

Open-loop frequency-response curves yield information about closed-loop operation. They provide, for example, the ultimate sensitivity and ultimate period, which are used in the closed-loop cycling formulas given above.

Examine the process in Figure 2C as described by its unmodified frequency response curves. To find the ultimate frequency, read the frequency at which the process has a 180-deg phase lag. Here this occurs at frequency $f_u = 0.27$ cpm. The ultimate period is $P_u = 1/f_u = 1/0.27 = 3.7$ min. From the graph the process gain g_u, at f_u, is 0.25 in./psi. The ultimate sensitivity S_u is given by the formula $S_u = 1.0/g_u = 1.0/0.25 = 4.0$ psi/in. These are precisely the same values of S_u and P_u as were found in the previous section. Therefore, recovery curve 2F is identical to curve 2E.

Settings for ¼-Decay Ratio

An earlier article[1] discussed the merits of the ¼-decay ratio as a criterion for setting proportional, proportional-plus-reset, and proportional-plus-rate action controllers. The graphical techniques for modifying the (normal) process gain and phase-angle curves which apply to a decay ratio of unity were also shown. The modified curves can be used directly for finding controller adjustments which will produce recovery curves having a decay ratio of about ¼. The procedure will now be demonstrated for three-term controllers, using the three-capacity process of Figure 2C.

If three modes of action are available in the controller, there are many combinations of controller settings that will give a recovery curve with a ¼-decay ratio. But since all recovery curves are not equally acceptable for good control, additional criteria are necessary. Practical experience shows that these criteria or conditions provide good control:

1) the recovery curve has a decay ratio of about ¼

2) the reset rate equals the operating frequency (the frequency at which the modified phase lag of open loop equals 180 deg)

3) the proportional sensitivity is set at maximum while satisfying conditions 1 and 2

Conditions 1 and 2 assure recovery of the con-

TABLE I

CONTROLLER SETTINGS FROM MODIFIED FREQUENCY RESPONSE

GENERAL PROCEDURE	EXAMPLE
STEP 1: Modify the process frequency response in the region of 180-240-deg lag.	See Fig 2C
STEP 2: Read the frequencies f_{180}, f_{210}, f_{240} at which the modified phase lag of the process is 180, 210, and 240 deg, respectively. Read the modified process gains g_{180}, g_{210}, g_{240} at these frequencies.	$f_{180} = 0.20$ cpm $g_{180} = 0.66$ in./psi $f_{210} = 0.28$ cpm $g_{210} = 0.33$ in./psi $f_{240} = 0.41$ cpm $g_{240} = 0.11$ in./psi
STEP 3: Calculate three combinations of controller settings from the formulas: $S = 1.08/g_{180}$, $U = f_{180}$, $T = 0.025/U$, (0 deg phase lead) $S = 1.05/g_{210}$, $U = f_{210}$, $T = 0.103/U$, (30 deg phase lead) $S = 0.74/g_{240}$, $U = f_{240}$, $T = 0.216/U$, (60 deg phase lead)	$S = 1.08/0.66 = 1.6$, $U = 0.20$, $T = 0.025/0.20 = 0.12$ $S = 1.05/0.33 = 3.2$, $U = 0.28$, $T = 0.103/0.28 = 0.37$ $S = 0.74/0.11 = 6.7$, $U = 0.41$, $T = 0.216/0.41 = 0.53$
STEP 4: Choose as optimum the combination of settings with the largest value of S.	In the example this is the combination $S = 6.7$ psi/in., $U = 0.41$ repeats/min, $T = 0.53$ min. If the controller is adjusted to these settings, it is to be expected that the recovery curve will have a 1/4 decay ratio and an operating frequency of 0.41 cpm (period $= 1/0.41 = 2.4$ min).

trolled variable from a load change with reasonable rapidity. And condition 3 assures small deviations of the controlled variable from the set-point.

Getting the settings that satisfy these conditions is not difficult for a noninteracting controller. Table I shows the general procedure alongside a specific example based on the process described by the modified frequency response curves of Figure 2C. The resulting recovery curve is shown in Figure 2G. The next section tells why this procedure works.

Figure 3A repeats the recovery curve of Figure 2G. This curve is the sum of several component curves: a damped oscillation (A), and two decaying exponentials (B and C). The decay ratio and oscillatory frequency of the damped oscillation A show up in the composite recovery curve.

If the damped oscillation is the dominant component in the curve—and it often is in the region of good settings—the decay ratio of both the damped oscillation component and the composite recovery curve are about the same. Figure 3B illustrates a recovery curve with a dominant damped oscillation. Thus condition 1, that the recovery curve has a decay ratio of *about* ¼, really means the controller is adjusted so that the damped oscillation A has a ¼-decay ratio.

Now, in the recovery curve 3A, computed from the settings found in Table I, component A is not particularly dominant (the decaying exponentials B and C do not die out rapidly). In spite of this, the settings give comparatively good control with small-amplitude deviation and small area under the recovery curve.

Derivation of Procedure

Where do the constants used in the general procedure of Table I originate? What is the basis for this simple yet effective method for finding satisfactory settings for three-term controllers?

The stability conditions for ¼-decay ratio (in a damped oscillatory component) require that, at the same frequency,

- ▶ modified gain of the open loop equals unity, and
- ▶ modified phase lag of the open loop equals 180 deg

These conditions are similar to the stability criteria for a decay ratio of unity in the closed loop.

Suppose the noninteracting controller is required to contribute a modified phase lead of 0 deg. Since the modified phase lag of the open loop must be 180 deg to meet stability conditions, this leaves a modified phase lag of 180 deg for the process. The frequency at which this occurs, f_{180}, is read from the modified process frequency response. This is the operating frequency, and so, according to condition 2, the reset rate is set equal to f_{180}.

As shown by the modified frequency response of the three-term controller, Figure 1, if the controller gives 0 deg in modified phase at the operating frequency (1.0 U) the product of reset rate and rate time UT equals 0.025. Since U equals f_{180}, the rate time T is easily calculated: $T = (UT)/U = 0.025/f_{180}$.

Finally, the proportional sensitivity must be adjusted so that the modified gain of the open loop is unity at f_{180}. The modified process gain g_{180} can be read from the process frequency response at

f_{180}. At this frequency the modified controller gain is 0.93 × S, the factor 0.93 coming from the additional gain due to reset and rate actions. To make the modified gain of the open loop equal unity the proportional sensitivity must be adjusted to

$$S = 1.0/(0.93 \times g_{180}) = 1.08/g_{180}.$$

These adjustments,

$$S = 1.08/g_{180} \qquad U = f_{180} \qquad T = 0.025/U$$

satisfy the stability condition for ¼-decay ratio in the dominant component of the recovery curve. These formulas are the ones used in Step 3 of Table I for 0 deg phase lead. They satisfy conditions 1 and 2, but the procedure must be repeated at several more points to assure satisfaction of condition 3, that of maximum proportional sensitivity.

Therefore, additional readings are taken at modified phase leads of 30 and 60 deg in the three-term controller. The corresponding process phase lags (which produce 180 deg in combination with controller lead angles in the open loop), are 210 and 240 deg. To get the additional 30 and 60 deg leads at 1.0 U to meet condition 2, the controller must be set at UT equals 0.103 and 0.216, respectively. Therefore, for 30 deg lead, $T = 0.103/U$ and for 60 deg $T = 0.216/U$.

Then the proportional sensitivities at f_{210} and f_{240} are found in the same manner that S was found at f_{180}. This results in $S = 1.05/g_{210}$ and $S = 0.74/g_{240}$. The combination of settings that results in the highest value of S should be used to meet three conditions for setting three-term controllers to give optimum recovery.

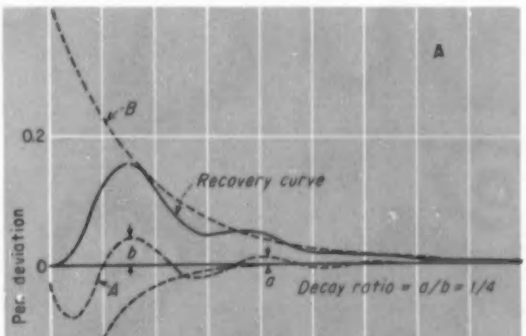
COMPARISON OF RECOVERY CURVES

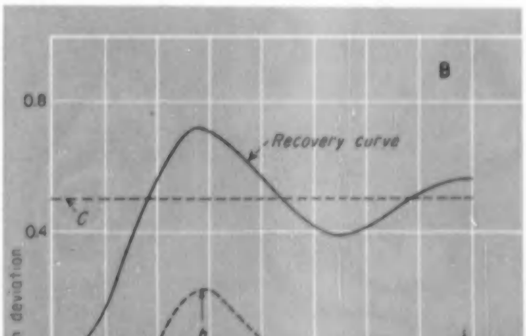
The process used as the example in computing settings by various methods consisted of *three* equal noninteracting time constants of 1 min. Its recovery curves (Figure 2) were taken on an analog computer. The curves show that these methods, all applied to the same process, result in different responses. Here, as the small deviation and the fast settling time of the curve indicate, settings based on the ¼-decay ratio appear to give the best control.

However, adding another time constant of the same magnitude to the above process results in a deterioration of controllability (Figure 4). Now the recovery curve based on continuous cycling of the closed loop gives a somewhat larger maximum deviation, although the process settles faster. As more time constants are added the controller settings based on the reaction curve give less stable results.

Figure 5 shows recovery curves for a process having one capacity (one time constant) and a distance-velocity lag. (In the analog it is necessary to approximate the distance-velocity lag by a special circuit[2]. This approximation causes an initial wiggle in the reaction curve rather than pure dead time L, but does not affect the remainder of the response.) This process has no self-regulation and thus has an

FIG. 3 A recovery curve contains several component curves. Figure 3A shows a nondominant damped oscillation, Curve A, and Figure 3B shows a dominant damped oscillation. When the oscillation is dominant a ¼-decay ratio in the damped oscillation means a ¼-decay ratio in the recovery curve—and good control. However, settings based on a nondominant case, as in 3A, still give fairly good control.





infinite time constant. Although theoretically the reaction-curve increases indefinitely, saturation does occur in the analog. The method of $\frac{1}{4}$-decay ratio gives a higher proportional sensitivity but a smaller product UT.

The last set of curves (Figure 6) is for a two-capacity process with distance-velocity lag and no self-regulation. For similar processes with the same reaction rate R_r and effective lag L_r, the sensitivity computed by the method of $\frac{1}{4}$-decay ratio decreases as the ratio L/T_2 increases. But the reaction-curve method gives the same computed sensitivity regardless of the ratio L/T_2, because this method depends on the values of R_r and L_r.

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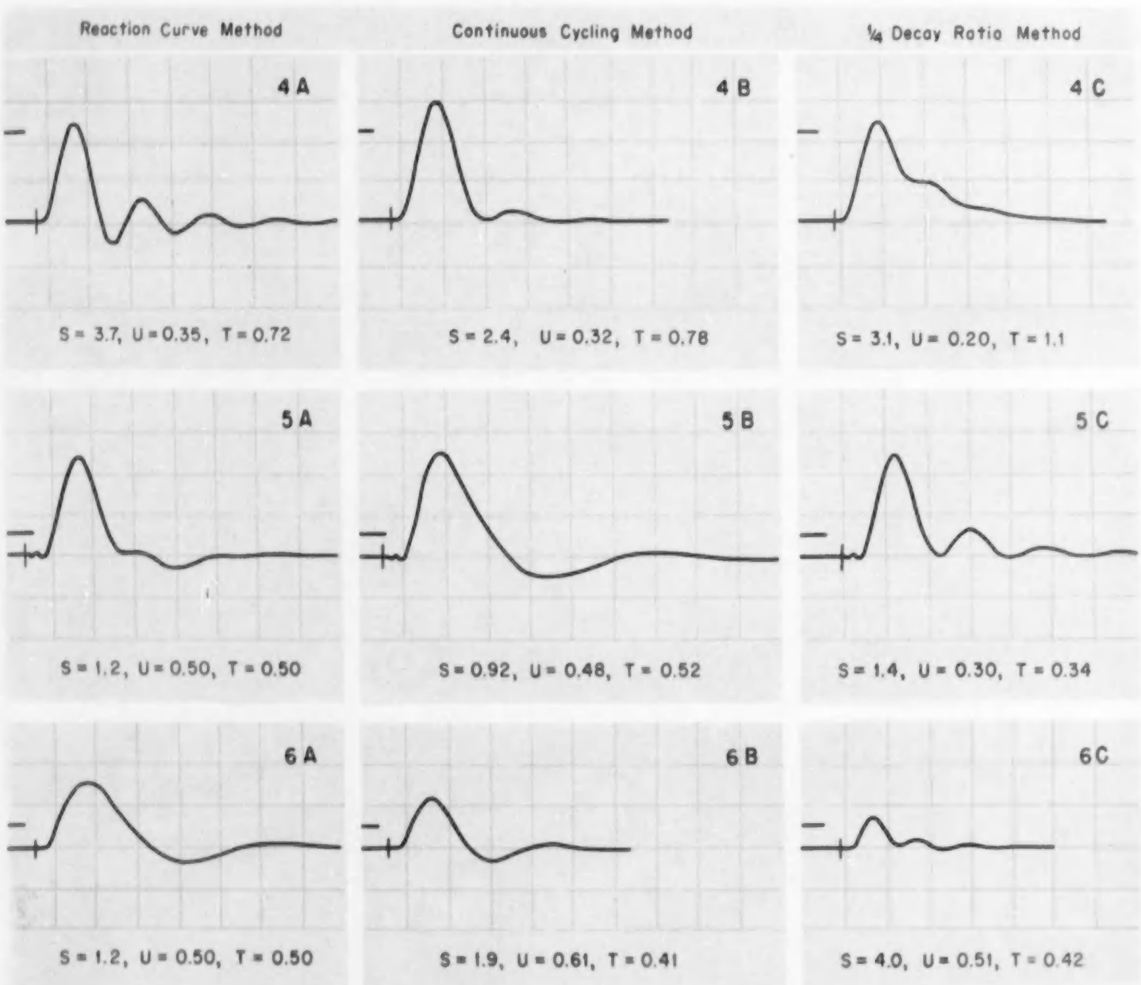
RECOVERY CURVES

FIG. 4. PROCESS: Four equal capacities, $T_1 = 1$ min

FIG. 5. PROCESS: One-capacity with distance-velocity lag and no self-regulation, T_1 infinite

FIG. 6. PROCESS: Two-capacity with distance-velocity lag and no self-regulation, T_1 infinite



IN ANALOGING . . .

Where You Should Use Series or Parallel Summation

THE GIST: The most elementary operation in analog computers is summation—that is, addition and subtraction. These operations can be carried out in a number of ways in electrical analog computing equipment. The two most common methods are series summation and parallel summation.

In discussing the relative merits of these methods, the authors point out many problems and impart solutions that result in desired equipment operation. Comparison of the methods of series summation and parallel summation are handily reviewed in an accompanying table.

G. WEISS and N. J. LINDNER, W. L. Maxson Corp.

In series summation voltage inputs are summed directly by connecting their sources in series. However, in parallel (or current) summation a current is derived by loading each voltage input source and these currents are added by connecting the voltage sources and loads in parallel.

Series summation allows no more than two addends directly connected to ground; any extra addends require isolation from ground. Since such isolation is not generally feasible in dc computers, series summation cannot be used under these circumstances. Thus a dc computer uses parallel summation almost exclusively.

In an ac computer either summation method may be used. Certain considerations, however, will influence the choice: series summation requires low voltages and low impedances, while parallel summation requires high voltages and high impedances.

Where vacuum-tube circuitry is used, either approach usually proves satisfactory, although series summation is more accurate for a small number of addends. Parallel summation may be preferred when accuracy is unimportant or when the number of addends is excessive.

In transistor circuitry, however, the choice of summation method is critical, because parallel summation, with its high voltage, high impedence, would require transistor amplifiers of greater size and complexity, and correspondingly lower reliability. Therefore, series summation should generally be used with transistor amplifiers. Incidentally, the reasoning applied to transistor circuitry for series summation applies to magnetic amplifiers as well.

SERIES SUMMATION

The generalized summation problem to be solved by the electrical analog computer takes the form:

$$S = A_1 X_1 + A_2 X_2 + \ldots\ldots + A_n X_n$$

where X_1, X_2, ... X_n are the addends and A_1, A_2, ... A_n are their coefficients. For simple addition all the coefficients are unity, but in the generalized case each coefficient may be *any* positive or negative number. The sum S may or may not be zero.

Obtaining the appropriate circuitry for the above relationship raises these problems:

1. Formation of the magnitude and sign of the "A" coefficients.
2. Isolation from ground.
3. Phase alignment.
4. Elimination of stray pickup.
5. Loading effect of wiring capacitances.

These problems are solved by the proper choice of isolation transformers and wiring techniques. The solution divides into these five steps:

- minimize effect of transformer inaccuracies by proper location of these transformers in the circuit
- minimize capacitive pickup by selection of order of addition of each addend with respect to ground
- minimize inductive pickup by pairing of wires
- minimize capacitive pickup by shielding
- minimize loading error due to wiring capacitance

A COMPARISON OF ELECTRICAL SUMMATION METHODS

	PARALLEL SUMMATION	SERIES SUMMATION
GENERAL REMARKS	Each voltage source (addend) and the output may be grounded. Works equally well in ac and dc circuits. Many voltages are summed as easily as a few. Results in high voltage, high impedance circuitry. Usually more convenient. To be preferred when accuracy requirements are moderate, or when the number of addends is large.	Only two of the sources, or one source and the output, can be grounded, unless transformers are used. Not easily usable in dc circuits. Difficulty increases as number of addends increases. Results in low-voltage, low-impedance circuitry. Usually most accurate. To be preferred when the ultimate in accuracy is required.
EQUIPMENT NEEDED	Usually requires an amplifier even if amplifier is not otherwise required in circuit. Extra amplifiers (for dc) or transformers (for ac) may be required for sign inversion. Requires summing impedances (resistors). Each partial sum requires a set of summing resistors and a summing amplifier. A "generalized sum" is handled as easily as a sum where all coefficients are unity.	Usually requires transformers, even if transformers are not otherwise required in circuit. Extra transformer may be required for sign inversion. Partial sums may require some additional transformers. A "generalized sum" may require extra transformers or resistors.
CHARACTERISTICS OF SUMMING EQUIPMENT	Feedback summing amplifiers must have high gain and accurate linearity. Summing resistances must be very accurate and stable. All transformers used for sign inversion or isolation must be accurate and linear.	Most summing transformers must be accurate and linear, and must have high input impedance.
SUMMING ERRORS	All sources are loaded. Variable source impedance of addends introduces loading error. Therefore, summing resistances must be very large, and source voltages high. Long-term stability depends on quality of summing resistors and on amplifier gain.	Some sources may be loaded by summing transformers. Accuracy preserved indefinitely, does not depend on component performance.
SCALING, TRIMMING, AND ADJUSTMENT	There is a loss of voltage scaling in the summation. Voltage scaling is easily adjusted with trimming resistors. Voltage scaling is easily changed by replacing the summing resistors.	There is no scaling loss in summation. Accuracy must be "built in". Trimming resistors not easily used. Voltage scaling can be changed only by changing transformers or transformer taps.
WIRING	Wiring is partially self-shielding. Wiring capacitance at sum point is critical.	Requires careful wiring to avoid inductive pick-up. Requires extra wiring tie-points. Shielded wiring may be required. Wiring capacitance has relatively little effect.
IMPEDANCE LEVEL	Requires high load impedances. Works well in vacuum-tube circuits. The summation point is a low-level, high-impedance point.	Summation can be performed into a low impedance load, with no current drawn from the sources. Works equally well with vacuum-tube, transistor, or magnetic-amplifier circuitry. The summation point is a low-level low-impedance point.

by proper physical location of transformers and wiring

Transformer Location

Transformers have three functions in the summation process. They determine the coefficient magnitude, invert the coefficient's sign if necessary, and isolate circuits from ground. The accuracy of summation depends on the turns ratio accuracy.

The transformer also constitutes a load on the signal source, and this causes loading error. However, in many cases the transformer can be located so that its transformation and loading errors are of no consequence. An example is when the total sum is brought to zero (as might be done in a servo) and the transformer is located in the null signal path. Figure 1A shows the functional diagram of series summation as it occurs in a servo system. Figures 1B and 1C show two available choices for connecting the transformer.

Figure 1A indicates that two summations, S_1 and S_2, are needed. Also, the inputs to both amplifiers (*AM* & *AB*) and the output of the tachometer generator G must all be grounded. Since it is impossible to ground these three points in a series summation, at least one transformer is required. In addition, the center-tapped potentiometer needs to be supplied scaling voltage from an isolation transformer since the scaling voltage supply is usually grounded at the power source.

These circuit requirements can be met in a number of ways, two of which are shown in Figures 1B and 1C. In Figure 1B the isolating transformer T_2 is located across the summation S_2. This arrangement requires high transformer accuracy and impedance. But in Figure 1C this transformer is located across the summation S_1, which is the servo's null signal. Because this signal is zero under steady-state conditions a transformer located at this point needs little accuracy and its characteristics are less critical.

In applications where the sum is not zero, all isolating transformers must be high-accuracy computing components. Here again, judicious location of the transformers minimizes error. If the transformer is located across any of the addend signals, for example, the accuracy of that addend will be affected by transformer error. Thus location across the smallest of the addends becomes desirable. It may be preferable, however, to locate the transformer across the signal representing the total sum. In this case, the summation is perfect, but the scaling of the sum is affected by the transformer error.

Order of Addition

Although the order of addition of the addends appears to be immaterial from a mathematical point of view (that is, $X_1 + X_2 + X_3 = X_2 + X_1 + X_3 = X_3 + X_2 + X_1$, etc.) it is most important from circuitry considerations. The circuit should be laid

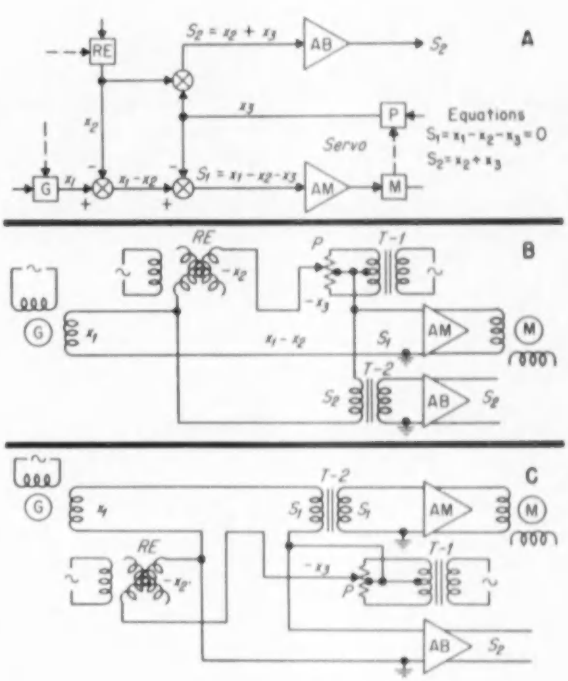


FIG. 1. Proper location of transformers in the circuit improves computer accuracy. Figure A shows the functional diagram of a servo. In Figure B the transformer is located across summation S_2. This arrangement requires a transformer with high accuracy and high impedance. But the circuit in Figure C, where the transformer is across the servo's null circuit, allows less exacting transformer characteristics.

out to minimize wiring capacitance to ground, and thus minimize capacitive pickup. In series summation, the addends are so arranged that the one with the smallest source impedance is the closest to ground and the one with the greatest impedance the furthest from ground. Figure 2 shows both the correct and incorrect ways of arranging three addends in series for minimum capacitive pickup.

Some computer components must be operated with one terminal at ground, regardless of internal impedance considerations. For example, amplifier inputs are always common with the B-minus return, which is ultimately returned to ground. This is an unavoidable situation in the conventional system, where one power supply and one B-minus lead is common to a whole computer.

Pairing of Wires

Inductive pickup can cause trouble in low-frequency ac computing circuits, primarily because it is often overlooked in equipment design. The most important source of inductive pickup is incorrect pairing of wires. Figure 3A illustrates how single wires running throughout the circuit form one big loop which picks up stray alternating flux. The same circuit, wired with twisted pairs as in Figure 3B, contains no loop area to introduce extraneous volt-

ages. The only additional equipment needed for wiring with twisted pairs is a wiring tie-post.

The reason for pairing is to reduce all loop areas to zero. Another way to say this is that the total current in every set of paired wires should be zero. Applying this rule, it is easy to determine the proper pairing, where the word "pair" is used in a generalized sense. That is, it may be required that three or more wires be twisted to reduce a given loop to zero. Care must be given to ground circuitry, for ground loops (duplicate ground wires or paths) make proper pairing difficult.

Shielding

Although shielding of wires minimizes capacitive pickup, it should never be done unless absolutely necessary, because it has several serious disadvantages. Shielding increases wiring capacitance, and shielded wire increases cost, is hard to work with, and is bulky. Shielding of summing transformers, on the other hand, does not significantly increase cost or size, and should be carried out routinely.

The need for shielded wiring can be established

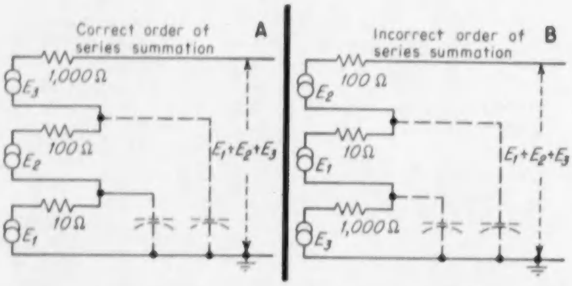


FIG. 2. In series summation the circuit with the smallest source impedance should be connected closest to ground and the circuit with the greatest impedance furthest from ground. Figure A shows the correct order, while Figure B shows an incorrect order.

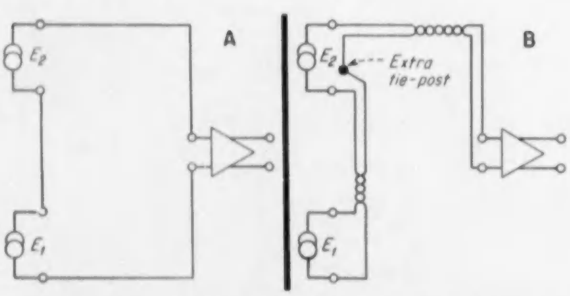


FIG. 3. Wiring of circuits with single wires allows detrimental inductive pickup due to the loop area, as shown in Figure A. But wiring with twisted pairs, as in Figure B, minimizes the loop area and therefore reduces the inductive pickup.

from this approximate formula:

$$E_{(pickup)} = 2\pi fCZE$$

where E = voltage that causes pickup
C = capacitance from voltage source to wire under consideration
Z = impedance to ground from wire under consideration
f = frequency

If calculations show that pickup may be excessive at any wire in a summation circuit, the *entire* circuit must be shielded, and the shields grounded. In some circuits, shields are connected to points other than ground; in all cases, however, they must be appropriately connected and never left floating.

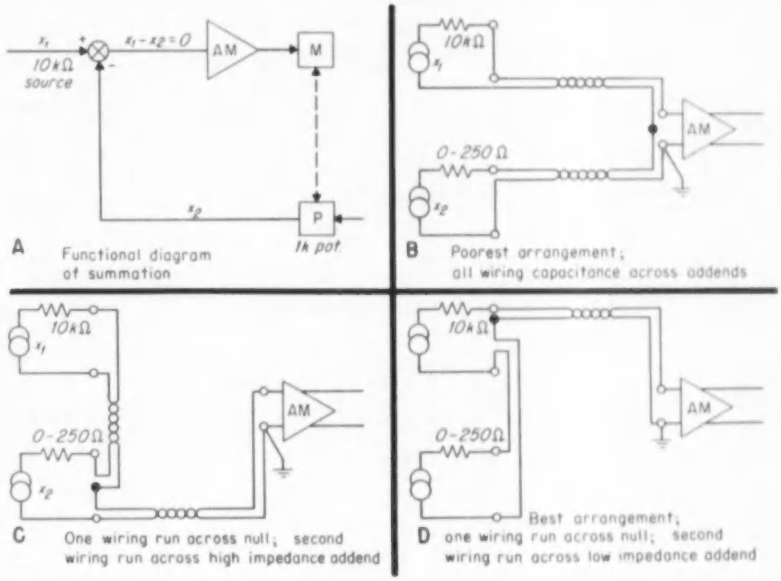
In parallel summation the pair of wires from each addend consists of a hot wire and a ground wire. The ground wire, when twisted around the hot wire, constitutes partial shielding; this makes it possible in many cases to dispense with shielded wiring. However, in series summation both wires in the twisted pair are likely to be above ground and shielding must be provided if pickup is excessive.

Wiring Capacitance Effects

The only source of summation error in a properly laid-out series summation circuit comes from wiring capacitance. Capacitance across any of the addends constitutes loading. Capacitance across the sum of the addends changes the scaling of the sum. These effects are not peculiar to series summation; they arise in parallel summation, too. However, the effects are less severe with series summation because of the lower impedance level. Furthermore, in series summation, the wiring can be arranged to minimize capacitance effects. If the sum is zero, the longest wiring run is placed across the sum. In general, the longest wiring run is placed across the smallest source impedance. Judicious physical location of isolation transformers also minimizes wiring capacitance effects. Figure 4 shows various ways to locate wiring runs for a simple potentiometer servo.

In some cases it may not be possible to keep the high impedance wiring run short. It then becomes necessary to neutralize the wiring capacitance by some other means. A common method is to shield the lead in question, and connect the shield to a point other than ground, usually to a low impedance point which has essentially the same voltage as the lead itself. Figure 5 illustrates the technique. Here X_1 is a high impedance source and X_2 is a low impedance source, both to be summed in series into a summing transformer, with the total sum being held to zero by means of a servomechanism, for example. If the circuit is wired conventionally, as in Figure 5A, capacitance C1 will be in parallel with X_1 and will cause a loading error. Shielding the wires, which may be necessary in order to minimize capacitive pickup, will increase the value of C1 and increase the loading error. The solution is shown in Figure 5B, where the hot lead only is shielded, and the shield is connected to X_2, not to

FIG. 4. In series summation the longest wiring runs of twisted pairs should be in the null circuit and across sources with the lowest impedances to minimize the loading effect of wiring capacitance. Figure D shows the best wiring arrangement for the functional circuit shown in Figure A.



ground. Since the total sum is held to zero, the potential on the shield will be the same as on the lead and no capacitive current can be drawn from it. The equivalent circuit shows how C1 is now located across the total sum. In a similar way the transformer stray capacitance C3, which also previously caused loading error, is rendered harmless by using a double-shielded transformer and connecting the inner shield to X_2. The capacitance loading on X_2 has been considerably increased, but this is not serious, because the internal impedance of X_2 is low. The important thing is that the capacitive loading on X_1 has been eliminated.

PARALLEL SUMMATION

There are two general methods of parallel summation. The first (and least used) is to sum open loop in a completely passive circuit. In the second, closed-loop summation, the summing point is held near zero potential by a high-gain amplifier or by a servomechanism.

Open-Loop Summation

Figure 6 shows the circuit for open-loop summation. Here the expression for the output voltage is:

$$S = A_1 X_1 + A_2 X_2 + \ldots\ldots + A_n X_n, \text{ where:}$$

$$A_i = \frac{G_i}{\sum_{i=1}^{n} G_i + G_o}$$

Each coefficient is less than unity, thus equivalent to a loss in voltage.

The admittance G_o is not required for summation itself, but may be required as a dc return for a circuit or to correct the overall scaling. In design, the summing admittances are determined, in accordance with the impedance levels desired and the required coefficients, from the following equations:

$$\frac{G_1}{A_1} = \frac{G_2}{A_2} = \ldots\ldots \frac{G_n}{A_n}$$

$$G_o = \sum_{i=1}^{n} G_i \frac{1 - \sum_{i=1}^{n} A_i}{\sum_{i=1}^{n} A_i}$$

Suppose, for example, it is required to compute

$$S = 1/3\ X_1 + 1/2\ X_2 + 1/10\ X_3$$

and suppose, too, that the minimum load on any source shall be 10,000 ohms ($G_{i\,max} = 10^{-4}$ mhos). Assume the source impedances equal zero.

Step 1. Compute $\Sigma A_i = 1/3 + 1/2 + 1/10 = 14/15$

Step 2. Compute $\frac{G_1}{1/3} = \frac{G_2}{1/2} = \frac{G_3}{1/10}$, or $3G_1 = 2G_2 = 10G_3$

Note that G_2 is the largest admittance.

Step 3. Let $G_2 = 10^{-4}$ **and compute** G_1 and G_3. $G_1 = 2/3 \times 10^{-4}$ mhos; $G_3 = 1/5 \times 10^{-4}$ mhos.

Step 4. Compute $\Sigma G_i = (1 + 2/3 + 1/5)\ 10^{-4} = 28/15 \times 10^{-4}$ **mhos**

Step 5. Compute

$$G_o = 28/15 \times 10^{-4} \left[\frac{1 - 14/15}{14/15}\right] = 2/15 \times 10^{-4} \text{ mhos}$$

Figure 7 shows the final circuit, with the computed admittances converted to resistance ($R = 1/G$).

Closed-Loop Summation

Figure 8 shows the general configuration for closed-loop summation. Here the exact equation for the sum S is

$$S = \frac{-\sum_{i=1}^{n} G_i X_i}{G_F} \times \frac{A}{A+1} \times \frac{1 - \frac{G_F}{AG_N}}{1 + \frac{1}{A+1} \times \frac{\sum_{i=1}^{n} G_i + G_o}{G_F}\left(1 + \frac{G_F}{G_N}\right)}$$

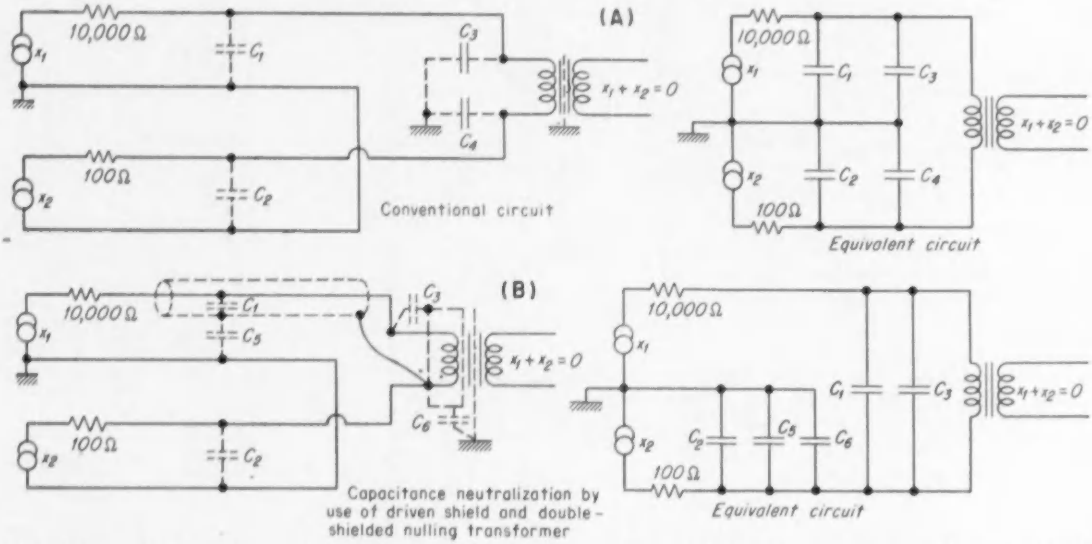


FIG. 5. The wiring capacitance of a long run can sometimes be neutralized by special shielding techniques. The conventional circuit, Figure A, will result in capacitance loading of the high impedance source. By shielding the hot lead and driving the shield from the low impedance side of the circuit, as in Figure 5B, the wiring capacitance is "neutralized", that is, it is shifted from the high impedance source to the null circuit. By using a double-shielded transformer and driving the inner shield from the low-impedance source, the transformer capacitance is also "transferred" to a harmless location.

In vacuum-tube amplifiers the output admittance G_s is low compared with the feedback admittance G_F and the input admittance G_o is very high compared with the summing admittances G_i. Under these conditions the third factor of the above exact summation equation may be modified and the equation reduced to:

$$S = -\frac{\sum_{i=1}^{n} G_i X_i}{G_F} \times \frac{A}{A+1} \times \frac{1}{1+\frac{\sum_{i=1}^{n} G_i}{(A+1)\,G_F}}$$

Let $\frac{G_i}{G_F} = A_{i\infty}$,the *i*th coefficient, with infinite amplifier gain. Now the sum may be written as:

$$S = -\frac{A}{A+1+\sum_{i=1}^{n} A_{i\infty}} \sum_{i=1}^{n} A_{i\infty} X_i$$

Note that the summing coefficients may be greater or less than unity.

The variation in output voltage with a change in a source impedance G_k is:

$$\Delta S = -\left(\frac{\Delta G_k}{G_k}\right) X_k$$

Thus a change in any source impedance affects only the output voltage contributed by that input.

Similarly, a variation in the feedback impedance changes the output voltage in accordance with:

$$\left(\frac{\Delta S}{S}\right) = \left(\frac{\Delta G_F}{G_F}\right)$$

A change in feedback impedance changes the voltage scaling from *all* inputs.

Amplifier Gain Required

How do amplifier gain variations affect summation accuracy? The gain sensitivity for high gain amplifiers ($A > 50$) is:

$$\left(\frac{\Delta S}{S}\right) \leqq \frac{1+\sum_{i=1}^{n} A_{i\infty}}{A}\left(\frac{\Delta A}{A}\right)$$

The change in gain with respect to changes in coefficients, or to addition or removal of an input, is:

$$\left(\frac{\Delta S}{S}\right) \cong \frac{\Delta\left(\sum_{i=1}^{n} A_{i\infty}\right)}{A}$$

This means that for very accurate summations inputs cannot be added or removed, nor can summation coefficients be changed very much from design values —unless the gain is very high.

In some instances, however, the number of inputs, or the coefficient values, must be varied, while the overall transmission stays at a constant level. Here, the input admittance G_o is deliberately made adjustable, and then, as the number of inputs varies, G_o is adjusted accordingly so that

$$G_o + \sum_{i=1}^{n} G_i = \sum_{i=0}^{n} G_i = \text{constant}$$

The overall gain thus becomes independent of the number of inputs or coefficients.

In designing for a variable number of inputs, the amplifier should first be made unconditionally

stable for the minimum number of inputs employed.

Effect of Source Impedance

So far the analysis has not included the effect of source impedance on the calculations. This effect can be computed in two ways as indicated in Figure 9. Figure 9A shows the actual summation circuit with the source impedance included.

The first method (Figure 9B), is to add the source impedance to the summing impedance, the result being an adjusted impedance (hence admittance). Then the overall transmission is computed using the source open circuit voltage. The equation for computing the admittance is shown in the figure.

The second method is shown in Figure 9C. Here the voltage source is loaded by the summing impedance and the consequent output voltage computed. This new voltage is used as the input to the summing impedance, with the source impedance assumed to be zero. The equation shown computes the signal directly. This method depends on the summing point remaining near zero potential, as is the case in closed-loop summation. Although both methods of analysis yield identical results, the second is the better one to use when the circuit contains variable source impedances, such as a potentiometer.

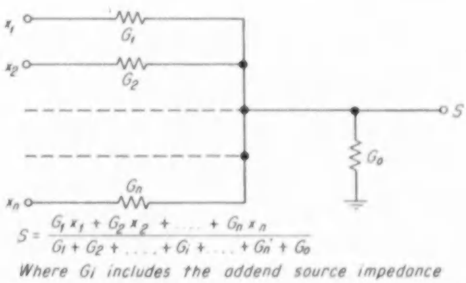


FIG. 6. This is the generalized circuit for open-loop parallel summation. Because it is a passive circuit, all coefficients are less than unity.

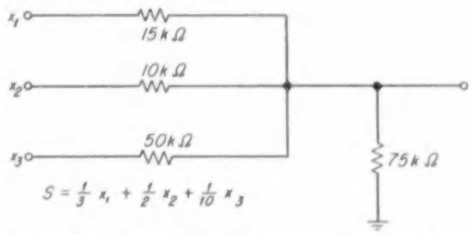


FIG. 7. The open-loop parallel summation problem explained in the text results in the impedances shown in this circuit.

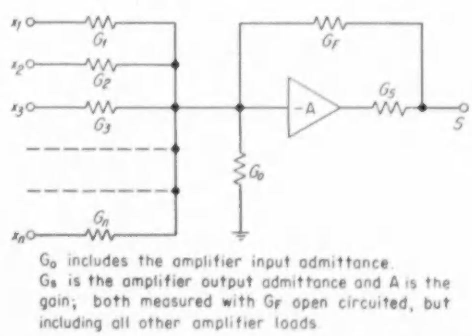


FIG. 8. This is the generalized circuit for closed-loop parallel summation. The minus sign associated with the amplifier indicates the usual sign reversal with respect to the input signal.

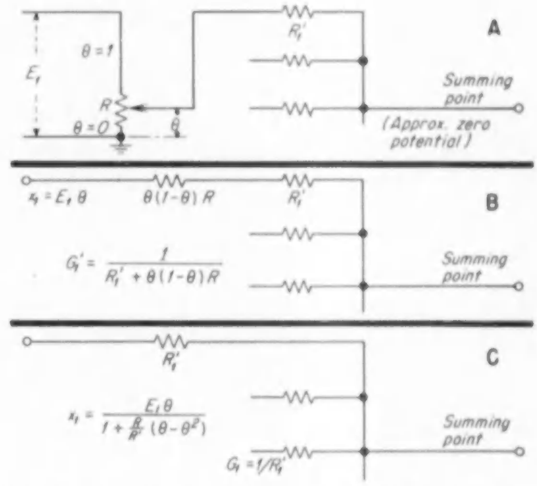


FIG. 9. In closed-loop parallel summation the effect of the source impedance R, as shown in Figure A, may be accounted for in either of two ways. In the method in Figure B, the source impedance is added to the summing impedance, the result being a modified admittance to be used with the open-circuit source voltage. But in the method in Figure C, the source voltage decreases somewhat as a result of the loading by the summing impedance. Now the total admittance of the input circuit is simply the reciprocal of the original summing impedance, and is used with the computed source voltage, assuming zero source impedance.

Wiring in Parallel Summation

The most critical point with regard to pickup in the parallel summation circuit is the summing point. It operates at a very low level with a fairly high impedance. All wiring to this point must be short, and should be shielded or run twisted with a ground return. The summing impedances, therefore, should be located inside the amplifier, and as close to the first stage as possible.

Voltage scaling adjustments in parallel summation should be made at the source side of the summing impedances.

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What to Look for in — Electrohydraulic Servo Valves

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THE GIST: Advances in hydraulic techniques and equipment have made possible hydraulic servos with large capacities and fast response. The electrohydraulic servo valve plays an important part in achieving adequate and reliable performance of hydraulic control systems. Its basic function is control of the large output power delivered to the hydraulic actuator with a low-power electrical signal. In a way, then, the valve is analogous to an electronic power amplifier.

Since the valve has a variety of configurations and types, the one selected and the way it is applied depend on the system in which it will be used, as well as its materials of construction, its static and dynamic characteristics, its reliability, and its environment.

The authors' work under WADC Contract No. AF 33(616)-2447 is the basis for this survey of basic valve types and construction, (Table I), selection and application, and features of commercially available electrohydraulic servo valves (Tables II and III).

Hydraulic servo systems offer considerably faster dynamic response than electric or pneumatic systems, particularly in applications requiring more than one horsepower at the load. This response comes from the

- high torque-to-inertia ratio of the servo's hydraulic actuator and additional advantages come from the inherently large power-to-weight and power-to-volume ratios of the actuator
- wide bandwidth and large power-handling capacity of the servo's electrohydraulic control valve

Table I reviews the major elements and forms of electrohydraulic servo control valves: valves that provide the system designer with effective components for severe control problems. This article treats the important design considerations in selecting these valves for system application.

TYPES OF CONTROL VALVES

Figure 1 shows the pressure-flow characteristics of various types of electrohydraulic servo control valves. Basically, valves control flow or they control pressure.

Flow-Control Valves

Flow-control valves are by far the most widely used. Their design incorporates either uncompensated or gain-compensated flow characteristics. In Figure 1 load flow is plotted as a function of load pressure, with the electrical input to the valve as a parameter. Here solid lines represent the normal, or uncompensated, flow-control valve. These solid curves show that the output flow decreases as the load pressure increases. This parabolic relationship

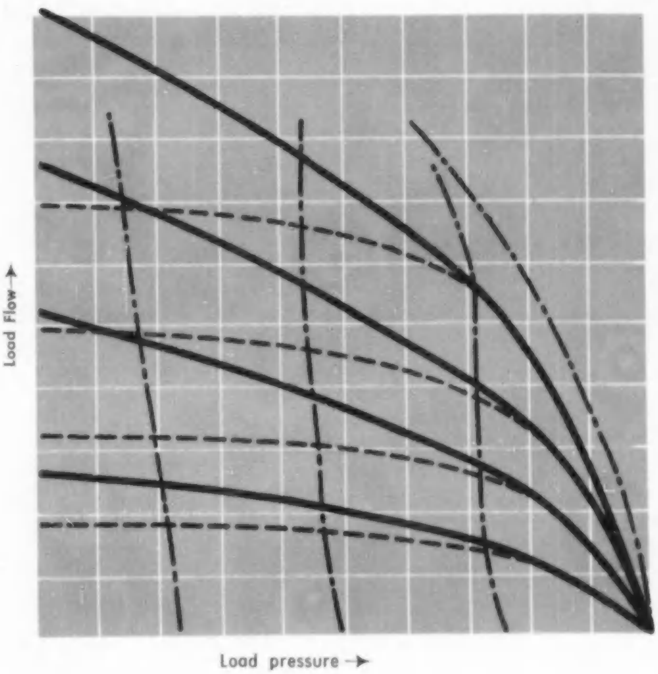


FIG. 1. Basic classifications of servo valves are uncompensated flow control, gain-compensated flow control, and pressure control. Here these characteristics are plotted with differential input current as a parameter.

comes from the Bernoulli formula:

$$Q = kx(\Delta p)^{1/2} \tag{1}$$

where: Q is the load flow
p is the valve orifice pressure drop
x is the input current
k is an orifice constant

Since the valve pressure drop Δp is related to the source pressure p_s and the load pressure p_l, as shown in Equation 2:

$$\Delta p_s = p - p_l \tag{2}$$

the Bernoulli formula becomes

$$Q = kx(p_s - p_l)^{1/2} \tag{3}$$

The flow gain of the valve (flow per unit of input current) derives from the partial derivative of Equation 3, taken with respect to x. Thus the flow gain equals

$$\frac{\partial Q}{\partial x} = k(p_s - p_l)^{1/2} \tag{4}$$

and depends, therefore, on load pressure, varying for different load conditions.

Gain-compensated valves minimize the effect of load pressure changes on flow gain. The dashed curves of Figure 1 show the characteristics of such a valve. Here the output flow is almost independent of the load pressure over a range of such pressures. Thus the valve's flow gain remains essentially constant within this range. Special construction allows over-compensation, with a resulting positive slope in the region of zero load pressure. Gain compensation is used where variations in gain would be detrimental in the servo, and where a constant velocity output under varying load conditions is desired.

Pressure-Control Valves

The dot-dash curves of Figure 1 represent typical characteristics of pressure-control valves. These curves, being nearly straight and vertical, show that the output pressure is almost independent of the load flow over a large range of load flows. Thus in this type of valve the load pressure is proportional to the electrical input.

Pressure control valves are used where the hy-

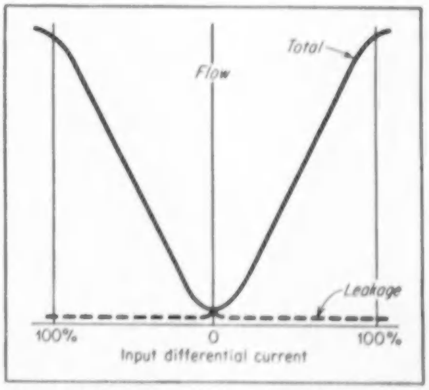


FIG. 2. Plot of a valve's output flow against input differential current. The flow gain is proportional to the slope of this curve, so the gain depends on linearity and symmetry of the curve.

draulic servo's load requires force or torque control rather than position or velocity control. This valve has theoretical advantages when used with high inertia loads or in systems with a considerable amount of oil under compression. However, these theoretical advantages may be offset in applications requiring appreciable flow because of the valve's poor dynamic response. This response degradation under flow conditions is apparently the result of the pressure compensation procedure.

STATIC CHARACTERISTICS

The system designer considers many factors about electrohydraulic servo valves when specifying one for a particular system. In addition to the pressure-flow characteristics already discussed, other steady-state characteristics of importance include: flow gain, maximum flow, steady-state leakage or quiescent flow, pressure gain, maximum pressure, hysteresis, threshold, dead zone, null shift, and input current.

Flow gain contributes to the overall loop gain of the servo system. As shown by the solid curve in Figure 2, the valve's gain depends on slope, linearity, and symmetry, as well as changes in slope due to load pressure changes.

Maximum flow rate depends on the peak rate of position displacement (velocity) of the output actuator. It is common in hydraulic system design to select a valve that supplies the required maximum load flow when the load pressure is two-thirds the supply pressure. Under this condition maximum power is transferred to the load.

Allowable quiescent power is set by the standby power available in the hydraulic system. Valves with nozzle-flapper first stages require about 0.1 gpm quiescent flow for the control stages. Figure 2 shows the leakage (quiescent flow) for the nozzle-flapper-type valve. The peak around null comes from added leakage of the second stage spool. This leakage is greatest with the output spool centered. Most systems allow for this steady-state loss, but it cannot be tolerated where the hydraulic power is derived from accumulators or limited-capacity pumps.

In any electrohydraulic servo system a certain amount of friction will be present and possibly some spring loading, too. Friction increases the amount of valve input current necessary to produce a measurable change in flow, while spring loading creates steady-state errors in the servo.

In a positional servo high pressure gain in a flow control valve minimizes these detrimental effects. Pressure gain is the slope of the pressure-differential current curve taken under blocked load conditions. Its value, which depends on the valve port's overlap or underlap, is usually very high for a closed-center flow control valve.

But a pressure-control valve has a relatively low pressure gain because its output pressure range extends over the entire current range of the valve. In this case good linearity and symmetry imply a fairly constant pressure gain.

The maximum required force coupled with the actuator's area determines the maximum pressure, which constitutes all or some portion of the supply pressure. Although this maximum force theoretically can combine the forces of acceleration, velocity, and steady-state operation, the actual combination will depend on the load and the desired response.

Three characteristics affect performance:

▶ hysteresis—the difference in flow occurring at zero input current as the current is cycled from zero over its entire range and back to zero

▶ threshold—the smallest input current necessary to produce a measurable change in flow, and

▶ deadband—the range of input currents around null (zero load flow) where the load flow of the valve remains essentially zero

The principal source of hysteresis arises in the magnetic circuit of the valve's torque motor. Secondary sources may be the motor and output stage springs, or friction within the valve. Low amplitude dither eliminates the hysteresis if it's due to friction, but not if it's due to the magnetic circuit.

Threshold, also due to internal friction of the valve, likewise may be reduced or eliminated by dither. The threshold might be considered a measure of the valve's sensitivity (not gain) where a small threshold value corresponds to a high sensitivity.

System operation determines the desirability of deadband, which develops from overlap at the ports of the output spool. Deadband is usually undesirable because of the nonlinearities introduced into the control action of the system. This effect can be reduced by the addition of dither of sufficient magnitude to cause the output spool to traverse the entire deadband. Small signals then cause some output flow on the peaks of the dither signal.

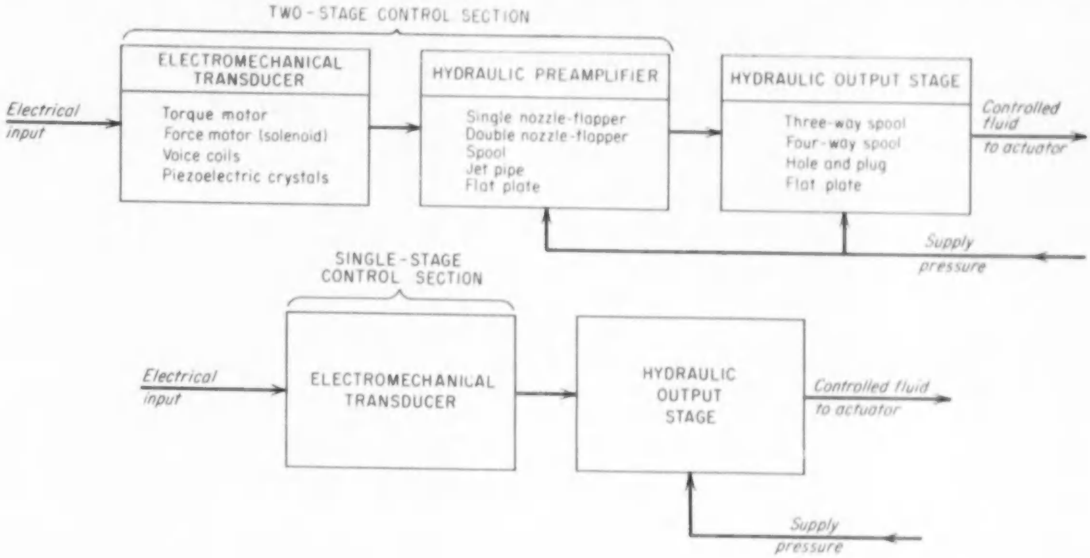
Most nozzle-flapper valves have low enough values of hysteresis, threshold, and deadband to make dither unnecessary. But valves using spools directly stroked by the torque motor (e.g., single-stage valves) usually do require dither.

Many valves exhibit a shift with respect to zero of the flow null (zero load flow) under varying conditions of temperature and supply pressure. Although the exact causes of these shifts are unknown, the most likely are changes in 1) magnetic characteristics of the torque motor, 2) orifice coefficients in nozzle-flapper valves, 3) physical dimensions within the valve, and 4) spring characteristics. This null shift amounts to as much as 1 ma (the differential current necessary to renull the valve) for a valve whose full input current is 8 ma. The extent to which valve null-shift affects servo accuracy depends on the servo loop gain. In general valves that employ an internal closed loop between stages exhibit less null shift than valves that operate open loop (such as those with a spring-restrained output stage).

The maximum differential current input for com-

TABLE I

BASIC CONSTRUCTION OF ELECTROHYDRAULIC SERVO VALVES

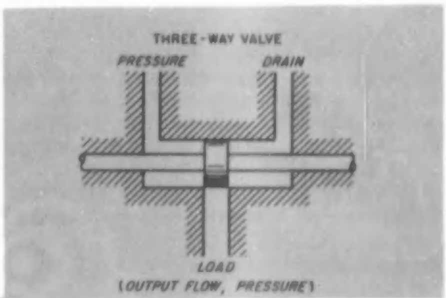


An electrohydraulic servo valve controls an hydraulic circuit by means of an electrical signal. Thus this valve converts an input current into an output flow or pressure, all three of these factors being interrelated in some characteristic manner depending on the type of valve.

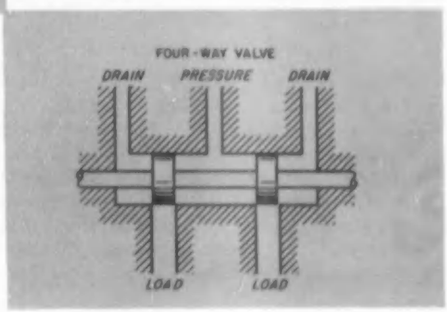
Electrohydraulic valves contain two basic sections: the hydraulic output stage, which controls the flow or pressure to the load actuator, and the control section, which positions the output stage in response to the electrical input signal. In some valves the control section contains an electromechanical transducer that directly drives the output stage. This configuration is known as a single-stage valve. In other valves the transducer drives an hydraulic preamplifier which in turn positions the output stage. This type is called a two-stage servo valve.

HYDRAULIC OUTPUT STAGE

A three-way valve (pressure-drain-load) contains two orifices in series between supply pressure and drain. The load-flow outlet is located between the orifices. Thus, whenever the movable element moves with respect to the valve body the area of one orifice increases while the area of the other orifice decreases. Pressure drops across the orifices likewise vary, forcing oil in or out of the load port. In this type of valve the load outlet pressure is always the same as the pressure drop across the drain orifice. Since the outlet pressure never becomes negative it drives the load actuator in one direction only. To obtain bidirectional operation a restraining force (a spring or an external pressure source) must be applied to the other side of the load actuator piston.

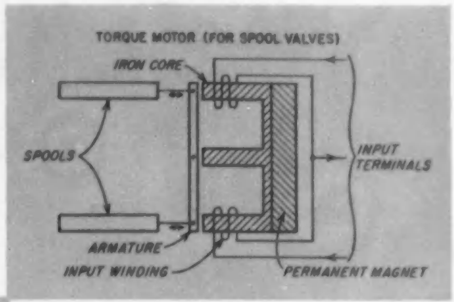


The four-way valve (pressure-drain-load-load) uses four orifices to control the load flow or pressure for bidirectional motion. Here one pair of orifices is used for each direction. Basically, the four-way valve operates as two three-way valves in push-pull. As the movable member moves in one direction the load pressure between one pair of orifices increases while the pressure between the other pair decreases. Because of this push-pull action the four-way valve produces a greater force output, is more linear over a larger range, and is less susceptible to supply pressure variations. But it has the disadvantage of increased costs. In servo applications the four-way valve is most commonly used.



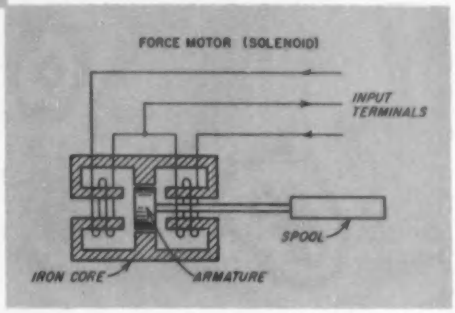
ELECTROMECHANICAL TRANSDUCERS

The torque motor (most common) contains a dc electromagnet and an armature. In addition, a permanent magnet is sometimes used to produce a bias flux against which the current-induced field reacts. In some cases the armature is part of the hydraulic amplifier. The armature rotates about a pivot and is spring-restrained. Current within the electromagnet creates a torque proportional (over a restricted range) to the current magnitude. The motion of the armature is rotary, although only of a small angular displacement.



TORQUE MOTOR (FOR SPOOL VALVES)

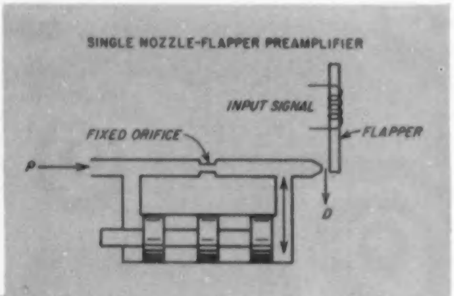
The operation of the solenoid as an electromechanical transducer is similar in principle to the torque motor, except that its armature motion is translational rather than rotary. Use of a solenoid results in a longer valve than does use of the torque motor, although the valve's cross-sectional dimensions may be smaller. Improved dynamic response is obtained from small-size transducers, and therefore the load driven by the armature should be kept to a minimum.



FORCE MOTOR (SOLENOID)

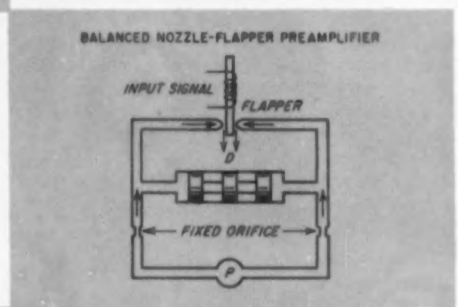
HYDRAULIC PREAMPLIFIERS

Hydraulic preamplifier stages take many configurations. In addition to the nozzle-flapper and jet types shown in this table, such stages may be either of the spool type used in the hydraulic output stage, or of flat-plate construction. In nozzle-flapper preamplifiers the flapper, located near the exhaust outlet of the nozzle, forms the armature of the torque motor. Any displacement of the flapper changes the effective area of the nozzle and hence the pressure drop across the nozzle. In single-nozzle-flapper design one of the orifices is fixed while the other orifice, formed by the flapper and nozzle, is variable. The fixed orifice is upstream from the flapper nozzle. Thus when the flapper moves toward the nozzle the pressure drop across the nozzle increases accordingly, with a corresponding decrease in the drop across the fixed orifice. The control pressure, applied to the spool of the output stage, equals the pressure drop across the drain orifice.



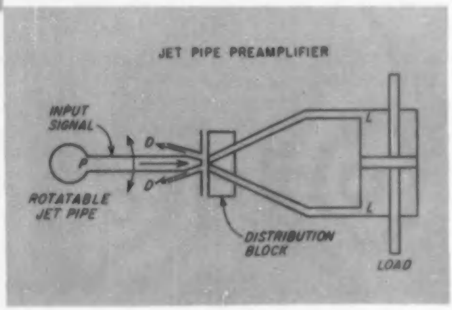
SINGLE NOZZLE-FLAPPER PREAMPLIFIER

In the balanced flapper preamplifier four orifices are used, two fixed and two variable from two nozzles. The nozzles are on each side of a single flapper. Here pressures upstream from each nozzle are applied to the ends of the output spools to give bidirectional controlling action to the hydraulic output stage. In double-nozzle preamplifiers the flapper's maximum displacement is limited to about 0.001 to 0.002 in., as compared with the total stroke of 0.005 in. of the single-flapper type. Both types of flapper-nozzle design give fast response and have small friction forces and no dead zone. But they have a high leakage rate when compared with spool-type preamplifiers.



BALANCED NOZZLE-FLAPPER PREAMPLIFIER

The jet-pipe preamplifier consists of a rotatable nozzle that aims a jet of oil at two adjacent orifices in a distribution block. Passages drilled through the block lead to opposite ends of the controlled member. When the jet nozzle points directly between the two orifices the recovered oil pressures at each orifice are equal and no displacement of the movable member occurs. However, if the nozzle is pointed more at one orifice, the developed pressure at this orifice increases while the pressure at the other decreases, resulting in a movement of the movable member. Due to its inertia the jet-pipe valve is limited in dynamic response, but it does have excellent reliability.



JET PIPE PREAMPLIFIER

mercially available valves ranges from about 2 to 40 ma. For a particular application the valve's exact rating can be specified. The present trend, particularly in aircraft control systems, is to use maximum currents of 8 to 10 ma. Even in industrial systems, these lower currents appear desirable.

DYNAMIC CHARACTERISTICS

The principal dynamic characteristic of interest to the system designer is the valve's no-load frequency response. Although the valve's response under load is also significant, these data are often more difficult to interpret and use.

How to Measure No-Load Frequency Response

The no-load frequency response of the servo valve relates the amplitude and phase shift of the output flow to the input current over the operating range of frequencies and is usually obtained experimentally. The measurement of output presents a problem, since it must be accomplished under the condition of negligible load. Probably the method most apparent is to utilize a dynamic flowmeter of the propeller or vane type. Unfortunately, the flowmeters which are presently available are not capable of measuring rapidly reversing flow at the frequencies and pressures that are of interest. The device the authors have used successfully consists of a small double-ended actuator coupled to the load ports of the valve through a manifold. Provision is made for measuring both piston position and velocity with a linear-motion potentiometer and linear-motion velocity pickup, respectively. The velocity of the actuator piston is essentially directly proportional to the output flow as long as the test frequency is kept approximately two octaves below the natural frequency of the piston mass and the effective spring due to the compressibility of the oil. By using a small cylinder with lightweight moving parts and a minimum volume of oil under compression, the natural frequency can be made in the order of one thousand cps, or higher, providing a large frequency range for measurement.

During the frequency-response tests, the peak-input differential current is maintained constant and the amplitude and phase of the velocity pickup is recorded at various frequencies over the operating range. A low-gain positional loop is maintained to prevent the actuator piston from drifting to one end of the actuator. Figure 3 shows a typical frequency-response curve.

Analysis of No-Load Frequency Response

Roughly speaking, the measured no-load frequency response of most valves exhibits characteristics that would be obtained from the single-order transfer function of the form: $1/(1+j\omega T)$. Thus the amplitude-ratio curve has a negative slope, after the

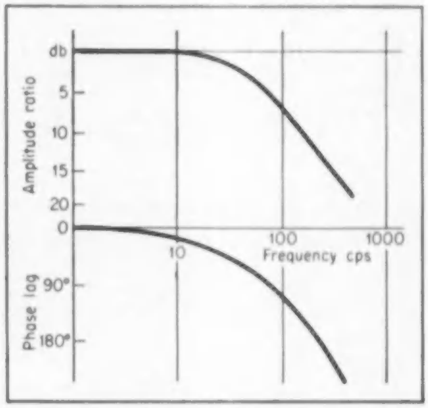


FIG. 3. No-load frequency-response characteristic of a two-stage servo valve is similar to that obtained from a single-order lag.

break frequency, of approximately 6 db/octave (20 db/decade). Here, of course, the break frequency occurs at the minus-3-db point and is usually in the range of from 30 to 170 cps.

But the phase-shift characteristics are not as well-behaved as the amplitude-ratio characteristics. In some valves the phase-shift curves do track the theoretical single-order characteristics with the 45-deg point coinciding with the minus-3-db amplitude point, but at higher frequencies the curves depart from the theoretical: the phase shift continues well beyond minus 90 deg. In other valves the phase shift at the minus-3-db point is much greater than would be expected from a single-order transfer function. This characteristic is apparent in valves that employ feedback and exhibit high break frequencies. For most two-stage valves a phase shift of 1 to $1\frac{1}{2}$ deg/cps occurs prior to the break frequency.

Since the load natural frequency is usually lower than the valve's break frequency, the phase-shift characteristic is generally of more interest than the amplitude curve. This is particularly true if the hydraulic system exhibits resonance within the servo bandwidth. In some applications very high response is desired and the amplitude characteristic is also of prime importance.

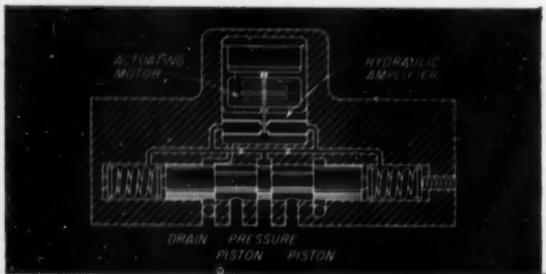
Valve Operation Under Load

When the valve operates under load its response becomes more a function of the load characteristics than of its own dynamics. That is, the load's characteristics, such as the natural frequency of the mass and effective spring constant of the oil under compression, predominate in the overall system response. From the frequency-response point of view this means the valve bandwidth is considerably in excess of the system bandwidth.

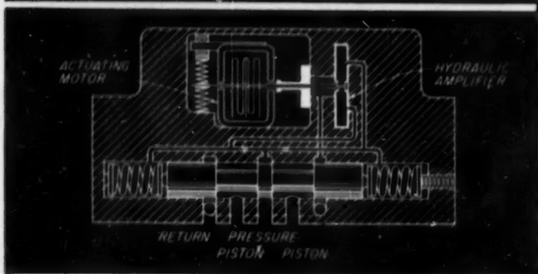
However the valve contributes system damping that can be correlated with the slope of its own pres-

TABLE II

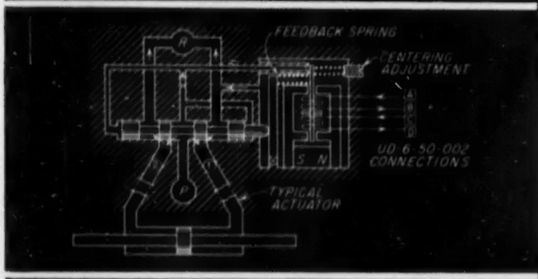
COMMERCIALLY AVAILABLE ELECTROHYDRAULIC SERVO VALVES



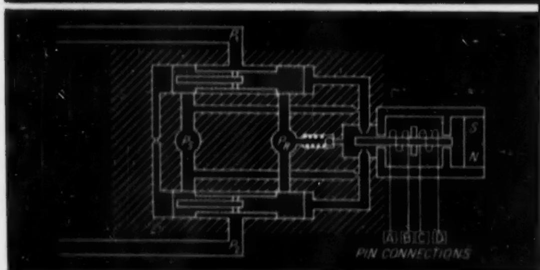
MOOG SERIES 500, 900 and 1400. These valves use a double nozzle-flapper first stage that drives a spring-restrained spool-type second stage. With this arrangement the flapper position produces a force on the output stage spool proportional to the differential current input. The spool position is proportional to this force. In the 500 and 1400 series the spool diameter is $\frac{1}{4}$ in. and in the 900 series it is 3/16 in. The first stage of all valves is protected by a 40-micron sintered bronze filter and a magnetic filter. Construction: hardened steel sleeve floated on "O" rings in aluminum body, and wet torque motor.



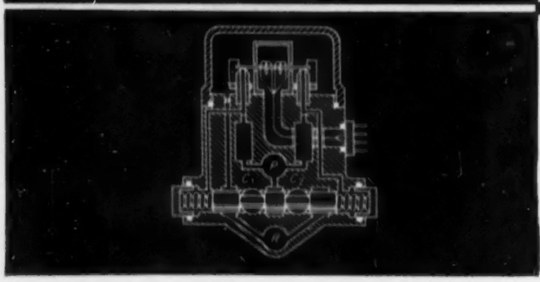
MOOG SERIES 2000. Same construction and operating principles as above, except dry torque motor uses a tube for sealing. Tube acts as flexure pivot for armature and flapper. No magnetic traps needed with dry design.



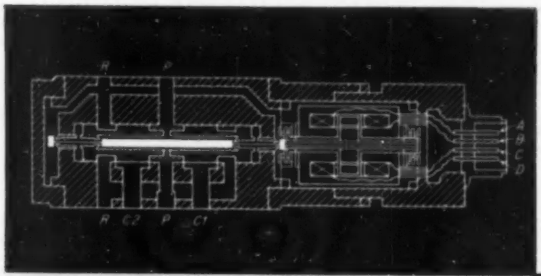
CADILLAC GAGE FC-2. Valve uses a single nozzle-flapper first stage driving a spool-type second stage. Pressure from hydraulic preamplifier is applied to full piston area at one end of spool and supply pressure is applied to one-half the area at other end. Internal feedback to torque motor is accomplished by lever and spring arrangement between spool and flapper. With feedback, spool follows position commanded by electrical input. First-stage filters: 40-micron sintered bronze and magnetic. Construction: hardened steel sleeve floated on "O" rings in aluminum body.



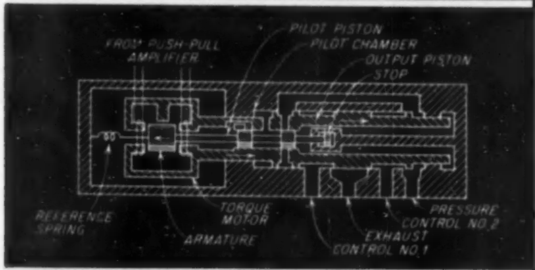
CADILLAC GAGE PC-2. This valve controls load pressure. It uses a double nozzle-flapper preamplifier driving two freely-floating pistons in the second stage. Pressure control is derived from a pressure proportional to load pressure. This balances second-stage spools against driving pressure (proportional to differential current) from first stage. The balancing pressure, created by flow through the hollow spools, builds up across fixed orifice in passage between dead ends of the spool chambers. Magnetic and 40-micron sintered bronze filters.



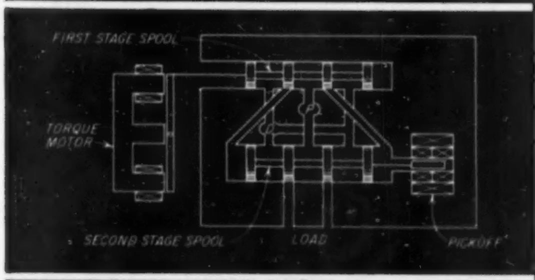
BENDIX PACIFIC HR SERIES. These valves use a double nozzle-flapper first stage that drives a spring-restrained second stage. Principle of operation is similar to other valves of same basic construction, but here the torque motor and nozzle-flapper assembly gives greater flapper displacements than conventional designs. Greater movement prevents clogging, and additional protection against this problem is provided by a 5-micron sintered bronze filter. Construction: steel body with hardened steel inserts.



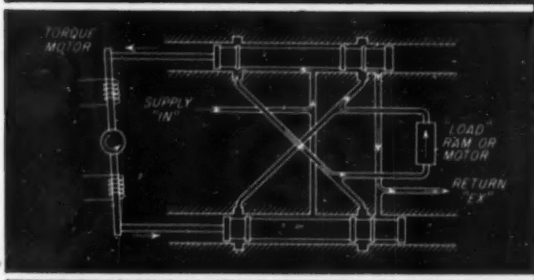
PEGASUS LABS MODELS 120-B, 140, AND 160. Pegasus valves use a quadruple nozzle-flapper preamplifier driving a spool-type second stage. In this unique design the nozzles are attached to the spool and are free to follow the flapper movement. A solenoid force motor, which drives the flapper, is sealed by a bellows seal from the nozzle-flapper chamber. This construction eliminates need for magnetic filters. 120-B valve uses a hardened steel sleeve in aluminum body, while the other valves use all-steel construction. Model 120-B shown.



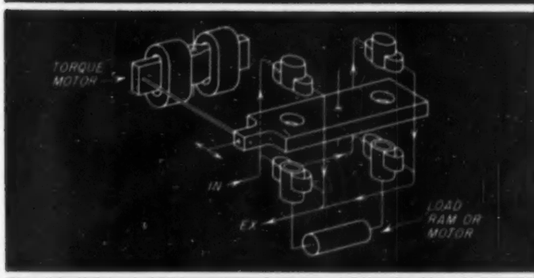
SANDERS SA14 AND SA17. SA14 valve (shown) uses a spool-type first stage driving a spool-type second stage. SA17 (a new design, not shown) uses a needle-nozzle first stage and spool second stage. In SA14 the force motor core and coils are attached to the second stage spool, with the armature spring restrained to the valve body. This construction permits large total armature displacement with a small relative motion between armature and core. SA14 has a wet force motor.



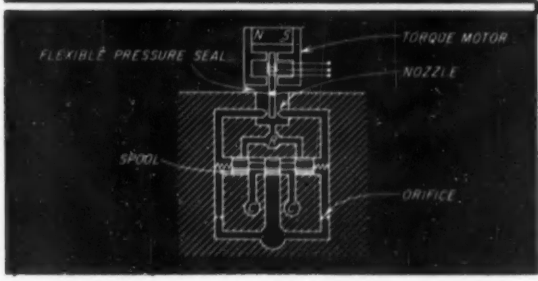
HYDRAULIC CONTROLS DS-2. In this valve a torque motor drives a spool first stage that controls a spool second stage. A linear differential transformer delivers an electrical signal proportional to second-stage spool position. The signal bucks the electrical input signal, and any difference is amplified, drives the torque motor, and thus closes the control loop. Therefore second-stage spool position is proportional to electrical input signal. The feedback arrangement allows a short-stroke fast-response torque motor. All-steel construction.



MIDWESTERN MODELS 3 AND 4. Both models are dual-spool single-stage valves driven by a torque motor. The spool arrangement forms a four-way valve insensitive to acceleration forces. Model 3 is flow-force compensated, but Model 4 is not. Both valves exhibit gain compensation to a considerable degree (which indicates Model 3 has incomplete flow-force compensation). The valves use all-steel construction.



MIDWESTERN MODEL 7. This valve uses a rotary flat-plate single stage with hole- and plug-porting. A torque motor (same as in other Midwestern valves) drives the plate. Flow-force compensation can be incorporated simply by adding baffles or deflectors inside the center hole of each load port. Valve uses all-steel construction.



BELL AIRCRAFT MODELS SV-6C AND SV-14C. (Manufactured by Hydraulic Research & Mfg. Co.) These valves use a double nozzle-flapper first stage driving a spring-restrained spool second stage. Principle of operation is same as other balanced nozzle-flapper valves. Depending on model, either "O" ring or bending tube sealing isolates the torque-motor coils from the oil flowing through the nozzles (dry construction). Internal filters clean oil supplied to the first stage. Valve constructed with hardened steel sleeve floated on "O" ring in aluminum body.

sure-flow curve. For instance, for a system in which the load natural frequency (due to inertia and oil compressibility) is within the bandwidth of the servo valve, experiment has shown that:

- the greater the slope of the pressure-flow curve the higher the degree of damping contributed by the valve, and therefore, that:
- gain-compensated flow-control valves contribute the least damping, and
- pressure-control valves contribute the greatest damping

But stable servo performance at high gain levels usually requires that this inherent valve damping still be augmented with additional damping.

In systems analysis it is helpful (and quite accurate in many cases as a first approximation) to consider the load response and the no-load response of the valve as separate uncoupled cascaded elements of the system.

PHYSICAL CHARACTERISTICS

Since the designer is seldom allowed unlimited space and weight, particularly in airborne installations, the physical characteristics of the servo control valve are important. Fortunately, many of the contemporary servo valves weigh only about 1 lb and are small enough to fit in one's palm. There are, of course, larger and heavier valves for industrial and marine use, but large size rarely means better performance. Small valves of all-steel construction, heavier than combination steel-aluminum valves, are useful when temperatures exceed 250 deg F.

Besides size and weight, the valve's adaptability to manifolding directly to the actuator deserves consideration, since direct manifolding minimizes the volume of oil under compression. A standard porting arrangement, used on over half of the commercially available valves, spaces the four ports equally on a base circle.

The valve's electrical connections differ among brands, and first-hand experience by the authors indicates that AN-type electrical connectors are most satisfactory. They meet military requirements and serve well in industrial applications.

VALVE RELIABILITY

A servo valve's reliability depends on the valve design, the quality of workmanship, and the system in which the valve operates.

The authors' experience shows that two-stage valves are more reliable than single-stage valves because of the higher forces available to move the output spool. And that nozzle-flapper first stages (even with their susceptibility to clogging) are more reliable than spool-type first stages. Here better reliability results from the force needed to move the flapper, which is small compared to the force required to move the spool. Adequate system filtration as well as internal oil filters minimize the nozzle flapper's potential clogging and improves reliability.

Dry torque motor valves, in turn, are more reliable than wet torque motor valves. In the latter, oil flows around the magnetic element which attracts magnetic particles in the oil, the eventual result being a change in the torque motor's characteristics. Magnetic filters in the valve circumvent this.

Quality of workmanship is of major importance in maintaining reliability. Even with the best valve design reliabilty diminishes with the presence of excessive tolerances, poor fits, insufficient clearances, and thermally unstable parts. Electrical defects also reduce valve reliability, and thus care should be taken to prevent opened or shorted coils and arcing between connector terminals. Placing a fuse in the line between the amplifier and the torque-motor coil prevents damage to the valve in case of amplifier malfunction or shorted coils. Limiting peak coil current increases reliability and can be accomplished with thyrite resistors (voltage-sensitive nonlinear resistance) connected across the coils. But because this added resistance increases the torque motor's electrical time constant, it should be used only where reduction in motor response is not critical.

HOW SYSTEM CHARACTERISTICS AFFECT SERVO-VALVE OPERATION

Environment and other system factors strongly influence performance and reliability of the electrohydraulic servo valve. Among these factors are:

- type of hydraulic oil used in the system
- extent of oil filtration
- oil's operating temperature
- ambient temperature
- pressure source
- length of supply lines
- type of actuator used
- driving amplifier

Hydraulic Oil

Selection of the hydraulic oil is dependent on the oil's viscosity, compressibility, flammability, solvent effect, wax-producing tendency, and operating temperature. Most military hydraulic systems use MIL-0-5606 hydraulic fluid because of its high viscosity index (i.e., relatively constant viscosity with changes in temperature).

A wide range of hydraulic oils or synthetic fire-resistant oils are found in industrial applications. Normal petroleum-base hydraulic fluids present few problems in commercially available servo valves, while synthetic oils present some major ones. One of them is need for a special packing material. Another need is for a finer degree of oil filtration, because the detergent and paint-removing properties of the synthetics introduce particles into oil lines.

Wet torque-motor valves (at present in the majority) can handle synthetic oils if protected by special electrical insulating materials. However, use of

a water-base synthetic fluid makes a dry torque-motor valve mandatory.

If system design allows the use of a synthetic fluid, a major advantage accrues: the higher bulk modulus of synthetics, as compared with petroleum-base fluids, raises the load's natural frequency and thus broadens system bandwidth and speeds up response.

Oil Filtration

Oil filtration within the system definitely improves the servo valve's reliability. Most valve manufacturers specify 10-micron filtration, with some variance above and below this number. The authors' experience shows cascading filters to be effective, and in this arrangement, the oil is first passed through a 10-micron filter element and then through a 2- to 5-micron element. These filters, of course, are in the pressure line upstream of the valve. To further guard against large particles that may enter during piping changes, a strainer is inserted at the valve inlet. A number of valve types incorporating these precautions were continuously tested for more than a year and there were no problems of clogging or sticking due to dirt. Another procedure that pays off is to filter the oil from the drums (these contain contaminators) before filling the control system.

Ambient Temperature

The oil and ambient temperatures at which the valve is to be used greatly influence the valve's design. For high-temperature applications (250 to 500 deg F) all-steel valves are more suitable than the steel-aluminum combinations. This single-metal construction reduces difficulties that would otherwise arise because of the difference in thermal expansions.

Other problems that arise because of high operating temperatures are changes in orifice coefficients and insulation breakdowns. Fortunately, a relatively constant and reasonable operating temperature (100 to 150 deg F) can be maintained by adequate cooling.

Pressure Source

Poor regulation of the pressure source adversely affects valve operation: the gain varies and the null shifts, and sometimes high-frequency pressure pulsations are produced, particularly from piston-type pumps. While these latter pulsations are of sufficiently high frequency and small amplitude to be absent from the servo output, they can cause fatigue of parts and unwanted resonances.

Pumps of the gear, vane, and radial or axial piston types are pressure sources of hydraulic systems. These, combined with relief valves, accumulators, unloading valves, and pressure compensators, produce a more or less constant pressure. The source's output then feeds the hydraulic servo valve and load combination.

Pressure-compensated pumps or relief valves give good pressure regulation. But unloading valves and accumulators, or simply a charged accumulator on a small system, give poor regulation. However, accumulators are effective in smoothing otherwise detrimental pressure pulsations to an acceptable level.

Supply Lines

The length of supply lines influences dynamic operation of the valve. Long lines mean reduced supply pressure at the valve and, more important, increased drain pressure. (In certain instances long lines created sufficient back pressure in the return line when the valve was suddenly opened to blow off the torque motor cover).

Actuator

The actuator is the output member of the hydraulic system. It delivers power, torque, or force to the system's load, as modulated by the servo valve. Actuators are either rotary motors or hydraulic pistons that produce a linear motion.

Rotary motors have greater internal friction and lower torque to inertia ratios than do comparably rated hydraulic cylinders. Actuator friction decreases the sensitivity of the servo system and narrows the system's bandwidth.

When used with four-way valves a double-ended cylinder provides equal forces and velocities in both directions of motion. And by proper choice of sizes, single-ended cylinders operated with three-way valves also achieve this balance.

Amplifier

Driving amplifiers for the torque motors of servo valves are usually direct-coupled with push-pull differential output. Unless the valve uses a high-inductance torque motor, which acts as a load on the amplifier, the amplifier's time constant is negligible. But suppose the torque-motor time constant is a limiting factor in extending the valve's frequency response to a satisfactory break frequency. In this case, current feedback techniques can be applied to increase the amplifier's effective output impedance with a resulting improvement in frequency response.

The 8-to-10-ma valves obtain their operating current from a dc dual triode output stage, while higher current valves need power pentodes. Dc amplifier drift can be minimized by using regulated power supplies, stabilized vacuum tubes, and temperature-stabilized components. Or low-level dc input signals can be choppered and amplified by ac amplifiers, with subsequent demodulation to deliver the required valve current.

HOW TO SELECT SERVO VALVES

The selection of electrohydraulic servo valves falls into several logical steps:

1. Determine system and load requirements
2. Compute actuator piston area

TABLE III

DYNAMIC AND STATIC CHARACTERISTICS OF COMMERCIALLY AVAILABLE ELECTRO HYDRAULIC SERVO CONTROL VALVES

MANUFACTURER & MODEL	SIZE	WT	MAX DIFF CURRENT	LOAD FLOW	QUIESCENT FLOW	TYPICAL FREQUENCY RESPONSE −3 db ampl. ratio Freq	Phase	Freq. at 90 deg lag
	(in.³)	(lb)	(ma)	(gpm)	(gpm)	(cps)	(cps)	(cps)
MOOG 500*	1.75 x 2.5 x 3.06	0.8	2 to 40 (usually 8)	0.5 to 8.0	0.1 plus 2% rated flow	62	70	92
MOOG 900*	1.75 x 2.5 x 3.06	0.8	2 to 40 (usually 8)	0.2 to 5.0	0.1 plus 2% rated flow	170	80	193
MOOG 1400*	1.75 x 2.4 x 3.5	0.85	2 to 40 (usually 8)	0.5 to 10.0	0.1 plus 2% rated flow	62	70	92
MOOG 2000	1.75 x 1.9 x 3.06	0.7	2 to 40 (usually 8)	0.5 to 8.0	0.1 plus 2% rated flow	59	70	100
CADILLAC FC-2	1.9 x 1.9 x 3.7	1.1	8 to 10	4.0	0.25	120	71	145
CADILLAC PC-2	2.0 x 2.0 x 3.2	1.3	8.0	7.7	0.25	100‡	30‡	180‡
BENDIX PAC. HR SERIES	2.32 x 2.65 x 2.14	0.91 to 0.99	6 to 20	up to 9.0	0.12 to 0.15	110 to 190	47 to 68	170 to 270
PEGASUS 120-B	2.0 x 2.0 x 6.0	2.0	30.0	5.0	0.13	185§	100§	135§
PEGASUS 140	1.87 x 2.18 x 7.5	3.0	40	10.0	0.21			
PEGASUS 160	3.0 x 3.0 x 9.0	15.0	40	20.0	0.26			
SANDERS SA14	1.4 x 1.0 x 3.58	0.7	40	4.0	0.13	100 (§)	105 (§)	83 (§)
HYDRAULIC CONTROLS DS-2	2.6 x 3.8 x 7.25	5.75	40	5.5	0.2	100		
MIDWESTERN 3¶	3.3 x 3.25 x 4.6	5.0	40	6.8	0.3	60	40	66
MIDWESTERN 4¶	2.9 x 2.5 x 4.0	2.8	40	4.3	0.2	50	60	60
MIDWESTERN 7	2.4 x 2.3 x 3.4	2.3	40	2.1	0.1	50	72	52
BELL SV-6C	1.4 x 2.6 x 3.3	1.0	10	2.0 to 7.5	0.25	60		90
BELL SV-14C	1.4 x 2.6 x 3.3	1.0	10	0.17 to 2.0	0.13	60		90

NOTES:
* May be gain-compensated
‡ Differential pressure versus differential current at zero load flow
§ Spool position versus differential current
¶ Dither generally required

Moog Valve Co.
Proner Airport
East Aurora, N. Y.

Bendix Pacific Division
11600 Sherman Way
North Hollywood, Calif.

Midwestern Instruments Co.
P O Box 7186
Tulsa, Okla.

Hydraulic Controls Co.
87 Terrace Street
Roxbury 20, Mass.

Cadillac Gage Co.
P O Box 3806
Detroit 5, Mich.

Bell Aircraft Co. Valves made by
Hydraulic Research and Manufacturing
2835 North Naomi Street
Burbank, Calif.

Pegasus Laboratories, Inc.
3690 11 Mile Road
Berkley, Mich.

Sanders Associates
137 Canal Street
Nashua, N. H.

3. Determine pressure-flow requirements
4. Consider maximum power transfer
5. Consider additional requirements

System and Load Requirements

System and load requirements vary from application to application. But usually sufficient information is available in each case to find:

- maximum force that must be applied to the load at any time
- maximum velocity of the load
- force at maximum velocity

The peak instantaneous load power determines the valve's power rating. This is the product of maximum load velocity and corresponding force moment. Maximum force requirements appear in many ways: in an aircraft application, for example, the maximum force depends on the maximum hinge moment specified for a control surface; in another application maximum force depends on the required maximum acceleration alone or in combination with friction forces.

The maximum velocity is generally specified directly. Other items known or specified include: maximum allowable quiescent power consumption, static accuracy, speed of response, and environmental conditions.

Computing Actuator Area

The maximum force (occurring at zero load velocity) applied to the load and the supply pressure determines the actuator area (assuming a linear actuator is used). Thus

$$\text{Actuator piston area} = \frac{\text{maximum force}}{\text{supply pressure}}$$

Supply pressure depends on such factors as cost, size, and weight. For instance, aircraft applications commonly employ a 3,000-psi supply pressure because it permits the use of smaller and lighter components. However, in industrial applications lower pressures are better because less expensive pumps and cylinders, and rubber hose rather than steel tubing, can be used.

Pressure-Flow Requirements

The maximum flow can now be computed:

$$\text{Max flow} = \text{actuator piston area} \times \text{max velocity of piston}$$

This calculation has the dimensions of length^3/unit time. From this the equivalent gpm of flow can be easily determined:

$$1 \text{ gal} = 231 \text{ in.}^3$$

The pressure required at this flow involves another simple calculation:

$$\text{Pressure} = \frac{\text{force at max velocity}}{\text{actuator piston area}}$$

Thus sufficient information is available to select the correct size of servo valve to suit the system and load requirements.

Maximum Power Transfer

Common practice dictates that the system be designed around the maximum power transfer of the valve. If this is done, the steps for selecting the valve are somewhat reversed. Dividing the force required at maximum flow by two-thirds the supply pressure determines the actuator piston area. The load flow then equals the product of the maximum velocity and the computed piston area. Since many valves are rated at two-thirds supply pressure, the maximum power transfer criterion facilitates valve selection.

Of course, it should be remembered that if a maximum force is specified, then it is still necessary to compute the maximum area accordingly so as not to exceed the force limitations. Also note that in a gain-compensated valve the maximum power transfer no longer occurs at two-thirds supply pressure and this criterion loses some significance.

Miscellaneous Requirements

Selection of the servo valve also depends on:

- allowable quiescent power consumption, which determines the maximum leakage, or quiescent flow
- static accuracy and loop gain requirements which determine the maximum allowable threshold, hysteresis, and deadband
- dynamic requirements, which depend on the dynamic requirements of the system, on the load's natural frequency, and on the loop gain previously stipulated by the static accuracy requirements. In this connection, the valve's bandwidth should exceed that of the load by at least a factor of two.

Little control can be maintained over the flow gain of the valve, as this is set by the maximum flow and the desired input current to the valve. But it is important that the flow gain remain relatively constant, except perhaps for small values of input current. Where gain variations cannot be tolerated and constant velocity is desired, a gain-compensated valve becomes useful.

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A DESIGN METHOD FOR

Feedback Stabilizing Transformers

H. B. JAMES, Westinghouse Electric Corp.

THE GIST: Transformers have long been used to add a stabilizing rate of change factor to the feedback signal in voltage regulator systems for dc generators. Today they are also finding application as "static-element" sources of rate signals in control systems that use magnetic amplifiers. Many control and regulating systems need stabilizing at frequencies lower than the low-frequency cutoff of the best audio transformers. Thus the problem arises of designing transformers to produce usable output voltages from very slow changes in their primary circuits. To make matters worse, these transformers generally must operate with large amounts of core-saturating dc in both primary and secondary windings.

In industrial generator-regulator systems, where size and weight are not too important, rate transformers have been designed by cut-and-try methods. But in aircraft systems, rate transformer inductances and time delays must be maximized for any given core size, in order to reduce size and weight. This article presents an empirical method for optimizing these time delays when core size and certain other transformer parameters are given.

Many industrial generator-regulator systems have combinations of time delays and time constants that are naturally fairly stable. And because the weight and volume of their components are not seriously restricted, the design of rate transformers for these systems has not been critical. In aircraft systems, however, the stability problem is quite serious because all of the time delays are of about the same magnitude. This, coupled with space and weight considerations, makes critical the design of rate transformers for aircraft electric systems.

In dc generator-regulator systems, the most common method of connection is to place the primary winding of the feedback stabilizing transformer across the exciter output terminals and the secondary winding in series with the regulator operating coil, as in Figure 1. This article deals with transformers designed to operate in circuits of this kind. Figure 2 shows a typical feedback transformer using two C-type cores.

The theoretical aspects of what the parameters of the feedback transformer should be are not considered here. The required transformer parameters would be determined by a mathematical analysis or analog computer study of the entire system.[7] Figure 3 includes a brief analysis of the feedback transformer circuit. Assuming that the required primary and mutual time constants T_p and T_m are known, this article discusses design considerations and presents some empirical data in order to provide these parameters in a suitable transformer.

DESIGN CONSIDERATIONS

The maximum effective inductance for a given core material and a given dc-ampere-turn bias is produced by an optimum air gap. A very important paper by Hanna[1], on the design of single-winding reactors that carry dc, develops a much-used three-

dimensional plot of inductance times dc current squared per unit volume versus dc ampere turns per unit length for given ratios of air gap length to core length. Such a surface is shown in Figure 4.

These surfaces are available for a number of different core materials[1, 2] and have been used extensively for the design of filter chokes and coupling and modulation transformers. For transformers, however, allowance must be made for the dc flowing in *both* windings. Usually, the primary and secondary windings are connected so that the dc ampere turns established by each winding are in opposition and tend to produce balance.

Dc Biasing Ampere-Turns

Balancing primary and secondary ampere-turns has limitations in voltage-regulator circuits because the primary winding is connected across the exciter output voltage, which can vary over wide limits in accordance with the excitation requirements of the main generator. Figure 5 shows the output variations over the operating range of a typical 20-kva aircraft generator. These variations are as much as four to one. The secondary winding is connected in series with the operating coil of the voltage regulator (Figure 1), and the dc current in the secondary, being proportional to the main generator terminal voltage, is essentially constant. Thus, the field due to dc in the primary winding is highly variable, and that in the secondary is constant. These fields can be balanced for only one condition of main generator excitation.

At first, it appears that the transformer should be designed so that the net dc magnetic field is zero at some nominal level of excitation, letting the unbalanced condition occur at both the high and low limits of excitation. A more satisfactory design is produced, however, if the zero-bias condition occurs where the voltage regulating system is at minimum stability, because the zero bias allows the maximum feedback stabilizing signal. Minimum system stability is always associated with low-excitation requirements. These requirements in turn are a result of high rotational speeds of the main generator and its directly-connected exciter, and light loads on the main generator. Refer to Figure 5.

The gain factor of the main generator and exciter varies directly with rotational speed:

$$e = Kni_f$$
$$\text{Gain} = e/i_f = Kn$$

where e/i_f is the voltage generated per unit of field excitation current, K is a constant of proportionality, and n is the rotational speed. Because minimum system stability occurs simultaneously with maximum gain, feedback should be maximum under these conditions.

As can be seen from the shape of the curves in Figure 5, the dc ampere-turns in the transformer primary will be quite appreciable at low speeds and

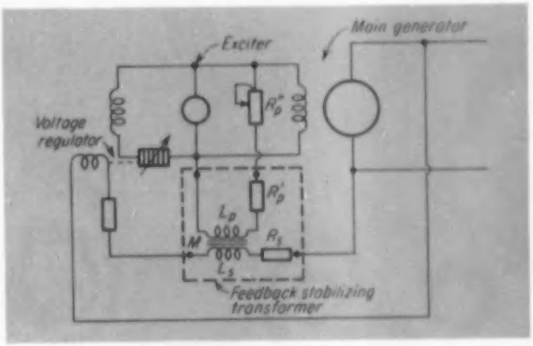


FIG. 1. A typical generator-regulator system using a feedback transformer.

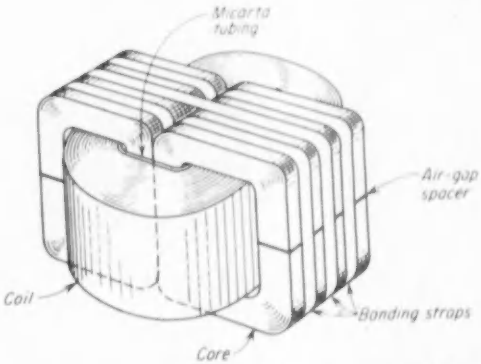


FIG. 2. Construction of a typical transformer using two type-C cores.

The feedback stabilizing transformer can be represented as:

This circuit can be described by the following two equations:

$$e_i = R_p i_p + L_p p i_p \qquad (1)$$

and

$$e_o = Mpi_p \qquad (2)$$

where
e_i = applied voltage to the primary
R_p = primary resistance
L_p = primary effective inductance
M = mutual effective inductance
e_o = output voltage
i_p = primary current
and p = d/dt, the differential operator.

Rewriting equation (1)

$$i_p = \frac{e_i}{R_p(1+T_p p)} \qquad (3)$$

where T_p = primary time delay L_p/R_p.

Substituting equation (3) into equation (2)

$$e_o = Mp\left(\frac{e_i}{R_p(1+T_p p)}\right) \qquad (4)$$

or

$$e_o = \frac{(M/R_p)pe_i}{1+T_p p} \qquad (5)$$

and

$$e_o = \frac{T_m pe_i}{1+T_p p} \qquad (6)$$

where T_m = mutual time delay M/R_p for a transformer with an unloaded secondary.

FIG. 3. A short analysis of feedback stabilizing transformers.

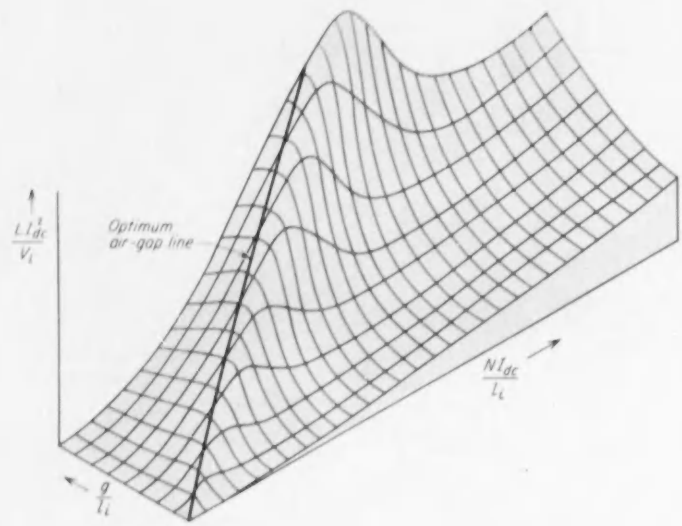


FIG. 4. Three-dimensional plot of transformer magnetic-core parameters attributed to C. R. Hanna.

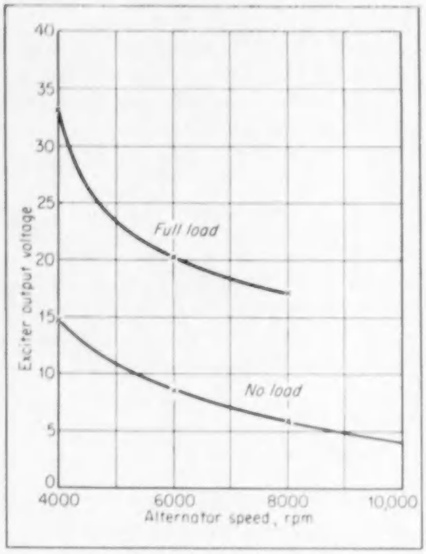


FIG. 5. Steady-state exciter output voltage vs. speed for a 20-kva alternator.

heavy main generator loading. The fact that the system gain is low under these conditions allows the feedback stabilizing signal to be reduced from that obtained at the high-gain condition for a comparable degree of system stability. In some cases, however, the saturating effect of the exciter at low speeds may be greater than the reduction of system gain, which could result in poor stability.

This situation could actually have beneficial action because the system response is inherently slower when the system gain is reduced, and, if the same feedback signal were used for all excitation levels, the system recovery time would be excessive for the low-speed, heavy-load conditions. A reduced feedback signal would allow a more rapid recovery.

Unfortunately, it is practically impossible to produce balanced dc ampere turns at the low-excitation conditions. The secondary ampere turns are so large that at minimum exciter voltage, the current in the primary would cause too much wattage dissipation. A compromise is necessary.

Allotment of Window Space

For any given core size, there is a definite window area available for the two windings. Generally, about 80 per cent is allotted to the secondary and the remaining 20 per cent to the primary, winding the primary outside of the secondary. This allows a maximum number of turns in the secondary and results in a maximum turns ratio, which is necessary to achieve the greatest possible mutual time constant, T_m. Sometimes 90 per cent is used for the secondary, but there is a limit because the mutual inductance M is a function of the primary inductance L_p. Allowing insufficient space for the primary results in diminishing returns, for as the turns ratio increases, the primary inductance decreases to such a degree that the product of the turns ratio and the primary inductance is less than before. Note that all the calculations in this article are based on an 80-20 division of coil space.

Secondary Winding

With a given core and given space available for the secondary, the length of the mean turn of the secondary winding can be calculated. To get the maximum number of turns possible in the secondary, a wire size must be chosen that fills the entire space with a total winding resistance not exceeding the maximum resistance allowable in series with the voltage regulator (see Figure 1). It is useless to try less than the maximum number of turns in the hope of improving the bias condition. The decrease in turns ratio and the resultant decrease in the mutual inductance would combine to give an overall decrease in effectiveness. It is always best to use the smallest wire size and the largest number of turns and amount of resistance.

Primary Winding

The primary winding design follows the same line of reasoning. With given core and given space available for the primary, the length of the mean turn can be determined for this winding. The maximum allowable wattage in the primary can be calculated using data from the secondary (in which

"DATA PERMITS QUICK COMPARISON OF FEEDBACK STABILIZING TRANSFORMER CORES IN AN AIRCRAFT ELECTRICAL SYSTEM"

TABLE I

COMPUTATIONS FOR FEEDBACK STABILIZING TRANSFORMERS USED ON AIRCRAFT ELECTRIC SYSTEMS

	DATA	29 GAUGE HIPERSIL TYPE "C" CORES						
		A-10	A-11	A-12	A-13	A-28	A-14	A-263
CORE DATA (PER CORE)	Gross Area	.469	.563	.75	.75	.947	1.00	.813
	Space Factor	.95	.95	.95	.95	.95	.95	.95
	Net Area (calc.)	.445	.535	.712	.712	.90	.95	.772
	Strip Width	1 1/4	1 1/2	1 1/2	1 1/2	1 1/2	2	1 5/8
	Build Up	3/8	3/8	1/2	1/2	5/8	1/2	1/2
	Window Width	3/4	15/16	15/16	1	3/4	1	3/4
	Window Length	2 5/16	2 1/2	2 1/2	3	2 5/16	3	2 5/16
	Weight	.91	1.17	1.63	1.82	2.00	2.42	1.72
	Length (calc.)	7.214	7.964	8.326	9.450	7.938	9.450	7.6
	Volume (calc.)	3.21	4.26	5.93	6.73	7.14	8.98	5.87
	Inside Radius	1/8	1/8	1/8	1/8	1/8	1/8	1/8
TUBE DATA	Length	2 1/16	2 1/4	2 1/4	2 3/4	2 1/16	2 3/4	2 1/16
	Inside Width	13/16	13/16	1 1/16	1 1/16	1 5/16	1 1/16	1 1/16
	Inside Depth	1 7/16	1 11/16	1 11/16	1 11/16	1 3/4	2 1/8	1 13/16
	Thickness	1/16	1/16	1/16	1/16	1/16	1/16	1/16
	Inside Radius	1/16	1/32	1/16	1/16	1/16	1/32	1/16
WINDING DATA	Cotton Travel	2 1/16	2 1/4	2 1/4	2 3/4	2 1/16	2 3/4	2 1/16
	Wire Travel	1 13/16	2	2	2 1/2	1 13/16	2 1/2	1 13/16
	Net Width for Wire	1.65	1.82	1.82	2.27	1.65	2.27	1.65
	Net Depth for Wire	.563	.751	.751	.813	.563	.813	.563
	Depth for Sec. Wire	.450	.601	.601	.650	.450	.650	.450
	Mean Turn (sec.)	6.31	7.28	7.78	7.93	7.94	9.31	7.56
	Area for Sec. Wire & Cotton	.816	1.202	1.202	1.625	.816	1.625	.816
	Depth for Pri. Wire	.103	.140	.140	.153	.103	.153	.103
	Mean Turn (Pri.)	9.33	11.12	11.70	12.10	11.20	13.69	10.76
	Area for Pri. Wire & Cotton	.187	.280	.280	.382	.187	.382	.187
	Approx. Total Cooling Surface	40	49	57.8	67.2	59.3	73.9	52.1
	W_t, Max. Total Watts	20.0	24.5	28.9	33.6	29.7	36.9	26.1

ALL DIMENSIONS ARE IN INCHES, SQUARE INCHES, CUBIC INCHES, AND POUNDS

TABLE II

EXAMPLE CALCULATION FOR FEEDBACK STABILIZING TRANSFORMERS USED ON AIRCRAFT ELECTRIC SYSTEMS

DATA	CORE SIZES						
	A-10	A-11	A-12	A-13	A-28	A-14	A-263
R_s Sec. Resistance	250	250	250	250	250	250	250
N_s Sec. Turns	4800	5600	5400	6400	4400	5800	4500
I_s Sec. Current	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_sI_s Sec. Amp-Turns	480	560	540	640	440	580	450
W_s Sec. Watts $I_s^2R_s$	2.5	2.5	2.5	2.5	2.5	2.5	2.5
W_t Total Watts	20.0	24.5	28.9	33.6	29.7	36.9	26.1
W_p Pri. Watts	17.5	22.0	26.4	31.1	27.2	34.4	23.6
E_{max} Max. Exciter Volts	30	30	30	30	30	30	30
R_p Pri. Resistance	51.5	40.9	34.1	29.0	33.1	26.2	38.1
N_p Pri. Turns	900	900	780	850	645	770	710
N_s/N_p Turns Ratio	5.34	6.23	6.92	7.53	6.82	7.54	6.34
$I_{p\,max}$ Max. Pri. Current	.583	.734	.880	1.035	.906	1.143	.788
E_{min} Min. Exciter Volts	5	5	5	5	5	5	5
$I_{p\,min}$ Min. Pri. Current	.097	.122	.147	.172	.151	.191	.131
$N_pI_{p\,max}$ Max. Pri. Amp-Turns	525	660	686	880	585	881	560
$N_pI_{p\,min}$ Min. Pri. Amp-Turns	87	110	115	146	97	147	93
$I_{dc\,max}$ Max. Eff. Current	.049	.111	.188	.282	.224	.389	.154
$I_{dc\,min}$ Min. Eff. Current	.485	.501	.545	.581	.531	.563	.503
$I_{dc}^2{}_{max}$ (Max. Eff. Current)^2	.0024	.0123	.0353	.0793	.0500	.1510	.0237
$I_{dc}^2{}_{min}$ (Min. Eff. Current)^2	.235	.251	.296	.337	.281	.316	.253
l_i Iron Length (cm)	18.4	20.2	21.2	24.0	20.2	24.0	19.3
$NI_{dc}/l_i\,_{max}$ (Amp-Turns/cm)$_{max}$	2.4	4.95	6.89	10.00	7.18	12.55	5.70
$NI_{dc}/l_i\,_{min}$ (Amp-Turns/cm)$_{min}$	21.4	22.2	20.0	20.6	17.0	18.0	18.5
$LI^2_{dc}/V_i\,_{max}$ (H-Amp^2/cc)$_{max}$	0.2	1.2	2.7	5.6	3.2	9.1	1.8
$LI^2_{dc}/V_i\,_{min}$ (H-Amp^2/cc)$_{min}$	18.8	20.0	17.3	18.0	14.2	15.2	15.7
g/l_i $\frac{\text{Air Gap}}{\text{Iron Length}}$	.0020	.0021	.0020	.0020	.0018	.0018	.0020
$S=g/2$ Spacer (Inches)	.0073	.0084	.0084	.0095	.0072	.0085	.0076
V_i Iron Volume (cu cm)	105.4	140	194	221	234	294	193
$L_{p\,max}$ (Pri. Inductance)$_{max}$	0.88	1.37	1.48	1.56	1.50	1.77	1.47
$L_{p\,min}$ (Pri. Inductance)$_{min}$	0.84	1.12	1.13	1.18	1.18	1.41	1.20
$L_p/R_p\,_{max}$ (Pri. Time Delay)$_{max}$	.0171	.0335	.0434	.0538	.0453	.0676	.0386
$L_p/R_p\,_{min}$ (Pri. Time Delay)$_{min}$	.0163	.0274	.0331	.0407	.0356	.0539	.0315
$L_{s\,max}$ (Sec. Inductance)$_{max}$	25.0	53.1	70.7	88.5	69.6	100	59.0
$L_{s\,min}$ (Sec. Inductance)$_{min}$	23.9	43.4	54.0	67.0	54.8	80.0	48.2
M_{max} (Mutual Inductance)$_{max}$	4.70	8.55	10.25	11.76	10.25	13.33	9.33
M_{min} (Mutual Inductance)$_{min}$	4.49	6.99	7.83	8.90	7.99	10.62	7.61
$M/R_p\,_{max}$ (Mutual Time Delay)$_{max}$	.0915	.209	.300	.405	.309	.510	.245
$M/R_p\,_{min}$ (Mutual Time Delay)$_{min}$	.0871	.171	.229	.307	.243	.406	.200
Total Core Weight (lb)	1.82	2.34	3.26	3.64	4.00	4.84	3.44
Pri. Copper Weight	.32	.55	.58	.83	.36	.94	.35
Sec. Copper Weight	.85	1.51	1.62	2.23	1.12	2.59	1.06
Total Copper Weight	1.17	2.06	2.20	3.06	1.48	3.53	1.41
Sum of Core & Copper	2.99	4.40	5.46	6.70	5.48	8.47	4.84
Final Calc. Weight	3.29	4.84	6.00	7.36	6.02	9.31	5.42
$\frac{\text{Copper Weight}}{\text{Iron Weight}}$	.64	.88	.67	.84	.37	.73	.41
Min. Mutual Induct./Pound	1.37	1.44	1.31	1.21	1.33	1.14	1.40
Min. (M/R_p)/Pound $\times$ 100	2.65	3.53	3.81	4.16	4.03	4.36	3.69

NOTE: THIS IS A THEORETICAL CALCULATION, USING INTERMEDIATE WIRE SIZES TO MAINTAIN CONSTANT CONDITIONS. ALLOWABLE WATTS PER SQ. IN. OF SURFACE=0.5W/□"

the current is constant) and a definite watts per square inch of radiating surface, based on the temperature ratings of the insulating materials used in the transformer (0.5 watts per square inch is used in this article). The allowable primary wattage is the difference between the total allowable and the secondary wattage.

The primary winding should have the smallest resistance possible. This value can be determined from the maximum exciter output voltage and the allowable wattage dissipation. A wire size can be chosen that is consistent with the minimum resistance value. Any smaller wire reduces both the turns ratio and the ampere turns in the primary. Resistance can always be added to the primary circuit.

Inductance and Time Constants

With the windings known, the primary effective inductance L_p, and the primary and mutual time constants, T_p and T_m, can be calculated. At minimum excitation they can be found as follows:

1. Knowing the minimum exciter output voltage, $(EOV)_{min}$, and the length of the given core, l_i, the net ampere turns per unit length of iron path is

$$\text{net}\left(\frac{NI}{l_i}\right) = \frac{N_p\,(EOV)_{min} - N_s I_s}{l_i} \qquad (1)$$

2. Hanna's curves can then be used to get the optimum air gap and the value of LI_{dc}^2/V_i.

3. The primary effective inductance is

$$(L_p)_{min} = \left(\frac{LI_{dc}^2}{V_i}\right)_{min} \times \frac{V_i}{(I_p)_{min} - N_s I_s / N_p} \qquad (2)$$

4. The primary and mutual time constants are then

$$(T_p)_{min} = \frac{(L_p)_{min}}{R_p} \qquad (3)$$

and

$$(T_m)_{min} = n\,(T_p)_{min} \qquad (4)$$

The same procedure can be used for any other exciter output voltage. The time constants can then be plotted as a function of the exciter output voltage.

EMPIRICAL DESIGN DATA

Given sufficient data on the core, insulation, and coil winding techniques, this procedure and the previous design considerations can yield the maximum time constants obtainable from any given core size. Tables I and II have been calculated on this basis for seven different Hipersil type-C cores. The cores in these tables all fall in the area of minimum size and weight for the time constants needed to stabilize aircraft generators. They could very well have been calculated for the larger cores and longer time constants necessary in industrial systems.

Because of the many variables and factors that must be considered in the design of rate transformers, it is necessary to take the more or less empirical approach represented by tables like those of I and II. The final data of these tables allow an immediate comparison of time constants, weights, and time delays per pound of total core weight.

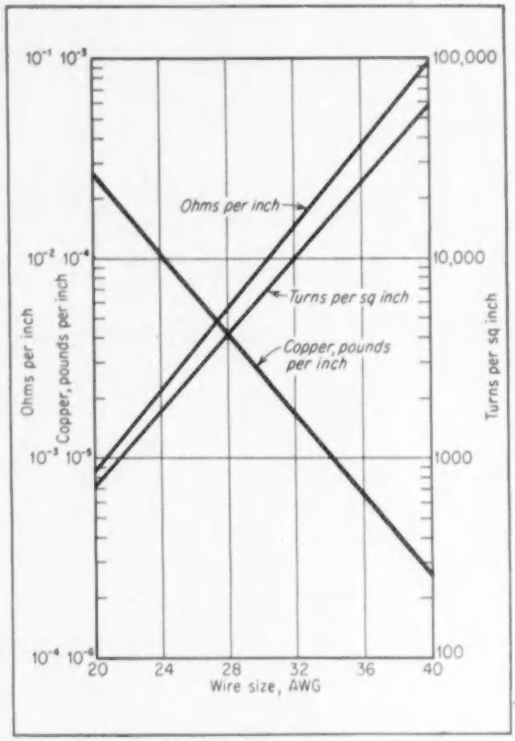


FIG. 6. Characteristics of double-layer enamel wire wound with cotton on Universal winding machine vs. wire size.

Core Material and Incremental Permeability

The cores used for all of the calculations in Tables I and II were made of Hipersil cold-rolled oriented steel. This 29-gauge (0.013-in.) core material is superior for this application to thinner laminations of similar material. In all such other cores, the incremental permeability is less.

Suitable information on incremental permeability is as scarce as information on the design of rate transformers. Very little published data on incremental permeability is usable for this application. In most cases the minimum ac flux density shown in such data is larger than that normally encountered in rate transformers. Because incremental permeability increases with flux density, the published data would be on the optimistic side.

Incremental permeability is probably the most important factor of the transformer, and therefore should be properly valuated for optimum design.

The data shown in Figure 10 were taken from

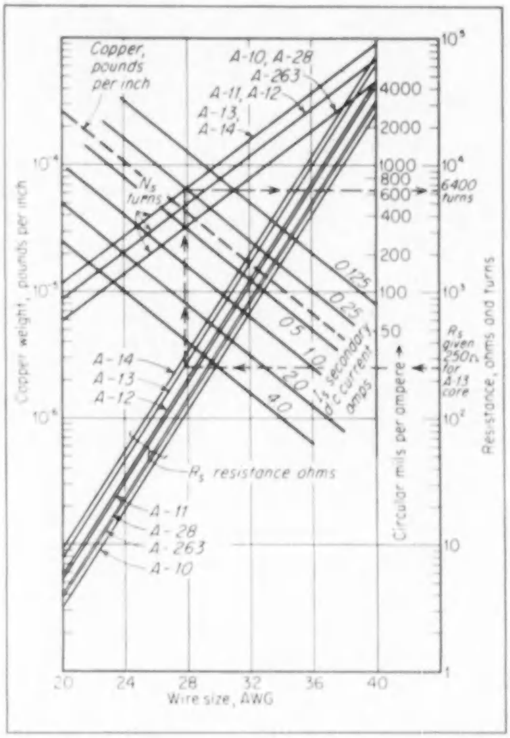


FIG. 7. Secondary resistance and turns vs. wire size.

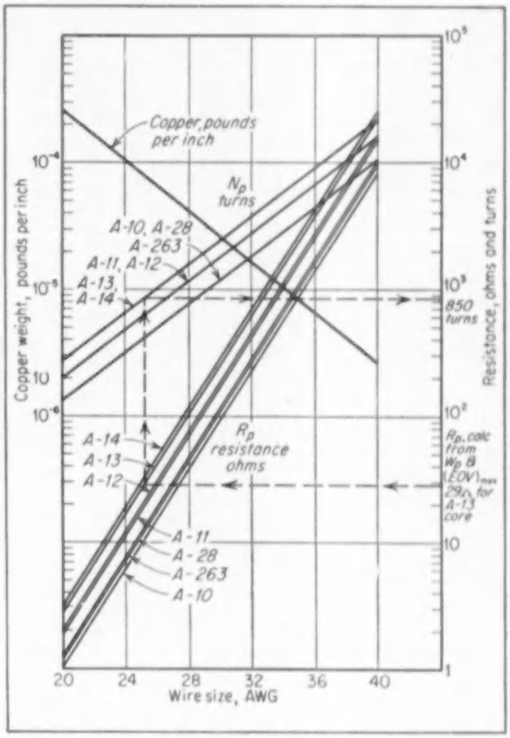


FIG. 8. Primary resistance and turns vs. wire size.

tests made at the Westinghouse Research Laboratory. This information was obtained using $\Delta B = 500$ gausses at a frequency of 60 cps. The Westinghouse Descriptive Bulletin 44–550 on Hipersil cores shows incremental data only to $\Delta B = 2$ kilogausses. Test values for typical transformers using Hipersil check very well with the data given in Figure 10. Also, the effect of the frequency of the varying signal is being studied for thinner laminations and certain bias conditions.

Core and Winding Data

The core data given in Table I is for the most part taken directly from Bulletin 44–550. The winding data are based on practices for low voltage aircraft transformers, where the coils are wound on Universal winders. Wire in all cases is double-layer enamel-covered or its equivalent. Allowances for insulation, clearance, etc., conform to standard practice on similar transformers. Available space for the secondary is 80 per cent of the total available space. The primary space is the difference, allowing for inter-section insulation. Also, the primary is wound outside the secondary. The miscellaneous data include the total effective cooling surface of the entire transformer and the total allowable watts, based on 0.5 watts per square inch. This is based on about a 60 deg C temperature rise at maximum power.

The curves of Figure 7 show the relationship between secondary winding resistance and turns as functions of wire size and core size. These are based on the allotment of 80 per cent of the available window area to secondary winding. The use of these curves to determine the number of secondary turns for the A-13 core is illustrated.

In the calculations in Table II, a fixed secondary resistance of 250 ohms was assumed, as was a fixed secondary current of 0.1 amp. Minimum primary resistance was based on a maximum exciter output voltage of 30 volts. Minimum exciter output voltage was set at 5 volts. Intermediate wire sizes were used to keep conditions constant between cores.

The curves for the primary winding, shown in Figure 8, illustrate the determination of the primary turns based on the maximum exciter output voltage and the maximum allowable primary dissipation. These curves also are based on the allotment of 80 per cent of the available window area to the secondary winding. The remaining area, less that necessary for insulation, is allotted to the primary.

Figure 9 shows Hanna's curves for 29-gauge Hipersil. These curves are a two-dimensional view

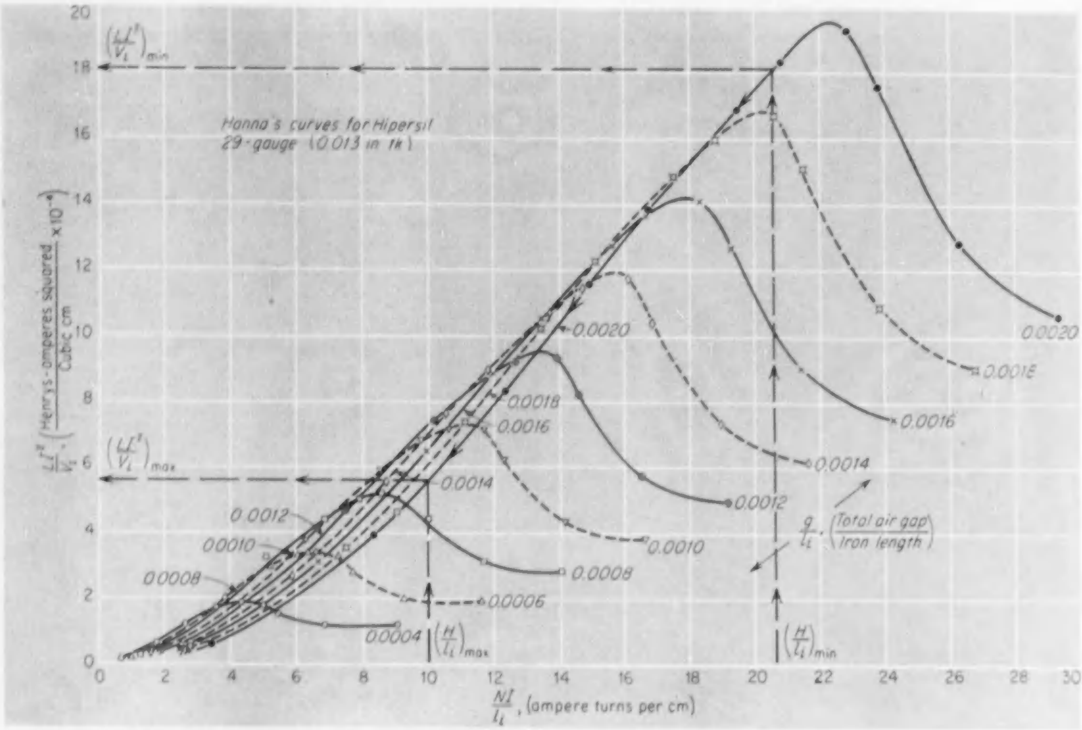
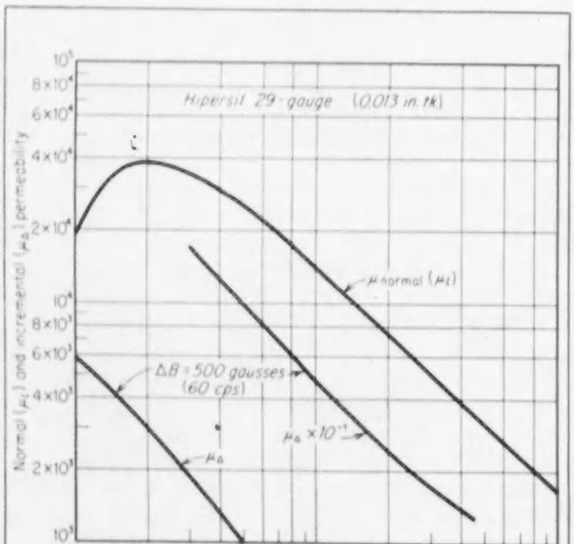


FIG. 9. A two-dimensional plot of the surface shown in Figure 4.

FIG. 10. Normal and incremental permeability of core material used in calculations.



of the surface shown in Figure 4. For a given value of ampere-turns per centimeter, as calculated from Equation 1, an air gap should be chosen to give the greatest value for LI_{dc}^2/V_i. An envelope of the curves in Figure 9 satisfies this condition. Note the heavy line in Figure 4. These curves also illustrate the calculations for the A-13 core. Note that the subscripts refer to the values of the parameters for maximum and minimum primary current.

The curves of Figure 11 were calculated on the basis of intermediate values of primary current, and show the effect of the varying primary current on the primary time constant, T_p.

TEST PROCEDURES

To evaluate transformer performance, certain independent constants should be known:

▶ direct-current resistances of the two windings
▶ self-inductances of the two windings
▶ mutual inductance between the two windings

A sufficient number of tests must be performed to provide the values for these five constants. The best test procedure depends on the type and rating of the transformer to be tested, the accuracy desired, and the apparatus available.

▶ the direct-current resistances of the windings can be measured with a Wheatstone bridge, or by the

voltage drop through the winding while it is carrying a known direct current

- the self-inductances may be determined from tests with one winding open-circuited
- the mutual inductance can be measured by connecting the two windings in series, both with aiding and opposing polarities. The resultant difference of these two values is then equal to four times the mutual inductance. Usually the measurements for these last two are made by means of a suitable alternating-current bridge (see references).

These measurements are complicated greatly by the nonlinear characteristics of the iron and by the core loss. Because of the latter, the apparent resistance of a winding when the other winding is open-circuited is not its effective resistance, but is a greater value. Furthermore, the values of the self and mutual inductances depend on the amplitude of the alternating flux density and, when there is direct-current in the windings, upon the value of this direct current. The inductance must therefore be measured under conditions that closely approximate the conditions of use of the transformer.

The values of inductance also depend upon the previous magnetic history of the core, since the residual magnetism has an appreciable effect on the apparent permeability of the core material. Still further, the apparent self and mutual inductances depend on the waveform of the flux variation and the measured values depend on the method of measurement. For all these reasons, to attempt to obtain precise results in the measurement of self and mutual inductances is useless, since it is practically certain that the values of the inductances under operating conditions will not exactly equal the measured values. Fortunately, however, the variations in the inductances are relatively small when the amplitude of the alternating flux density is small, as is usually the case in feedback stabilizing transformers.

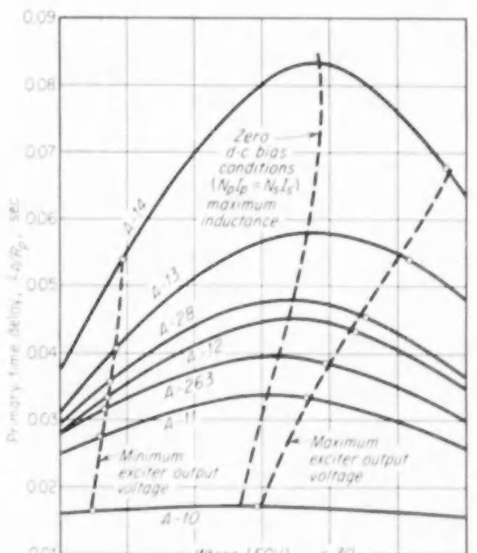


Fig. 11. Primary time delay vs. primary dc current for transformers of Table II.

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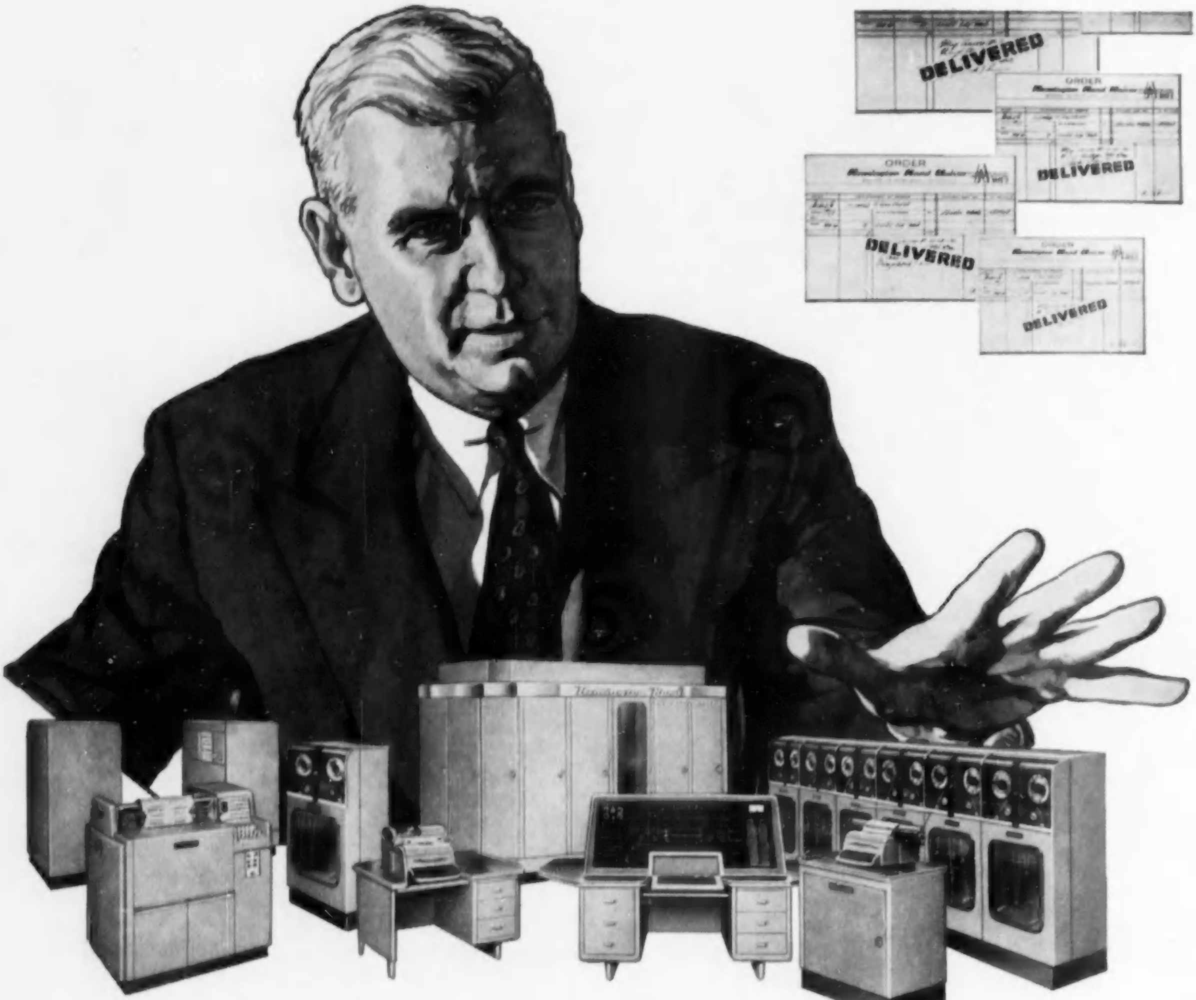

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Processing Business Data

Business-data processing consists of putting names and numbers through the operations associated with managing a business enterprise. But such operations (filing, calculating, deciding, and documenting) are only the mechanics of business systems. The real points of interest here are:

▶ What are the functions of business-data-processing systems?

▶ How do these systems differ from those used to solve scientific problems or control industrial systems?

▶ What are the data-processing characteristics of various types of businesses, their similarities and differences?

Author Adams lists three major functions, points out that business-data-processing systems are distinguished from other systems by a tremendous amount of input and output information and an inherently large data file, and discusses two data-processing problems: inventory control and payroll.

CHARLES W. ADAMS
Creole Petroleum Co.,
Caracas, Venezuela

Business-data-processing systems, or management information systems as they have been aptly called, have three principal functions:

1. To perform routine record-keeping, computation, and decision-making programs based on precise policies and procedures.
2. To accumulate, as an important by-product of the routine work, a collection of statistical medians, means, extremes, and other measures of effectiveness.
3. To serve as a computational tool in arriving at a valid basis on which company policies and procedures can be formulated and modified.

Thus, business uses computers for both routine clerical decisions, and for managerial decisions that require some amount of a not-yet-mechanizable function called judgment.

BUSINESS VS. OTHER DATA-PROCESSING SYSTEMS

The principal difference between business data processing and industrial systems control is often assumed to be the large data file usually associated with business problems. Actually, however, the file is just a symptom, not the source of the difference. The real difference seems to be the respective concerns of the systems: industrial systems control is concerned with *devices*, while business control is concerned with *people*. In industrial control, an electrical impulse or some other signal is used to regulate the flow of power that motivates various devices; while in business, printed documents or other means are used to regulate the flow of money and the intangibles that motivate people.

Usually, a business system consists of a large number of low-frequency components (people), widely dispersed geographically and largely unpredictable in behavior. Given an analogous problem, namely that of controlling a large number of closely interrelated, slowly varying elements, an industrial-systems engineer would naturally consider time multiplexing of equipment. Similarly, rather than associate a slow, simple data processor with each employee, stock item, supplier, and/or customer, a business-systems engineer sets up a file containing data on each person or element, and time-shares fast, efficient arithmetical and logical circuitry between the various accounts. Thus, the long, simple, redundant programs and the large data file are merely the result of time-sharing one powerful tool between numerous similar and simple jobs.

Business-data processing deals with changing situations in a social environment and usually exerts an influence on these situations. It is characterized by inputs from people and outputs to people, each input relating to one of many different items stored in a file of constantly changing historic data. Almost all business-data processing centers around the problem of relating each input to the proper item in the file, performing the indicated computations, and making the indicated decisions. Figure 1 shows this general procedure.

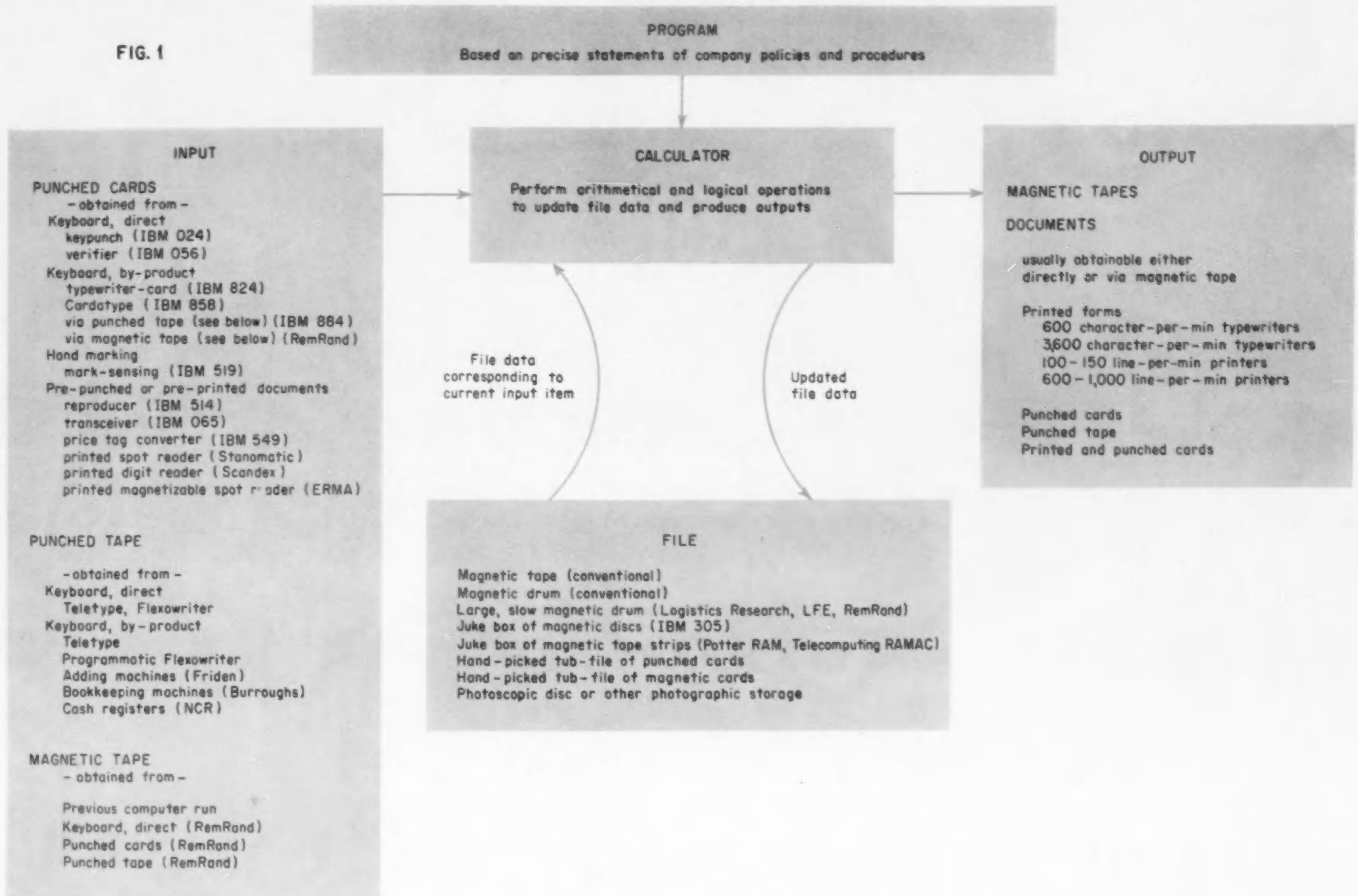
Looked at another way, business-data processing can be said to embrace:

- ▶ *data transcription* — transcribing data for input to the system and output from it
- ▶ *filing*—gaining access to filed data and, if necessary, modifying or adding to update the file, and
- ▶ *computing*—performing the arithmetic and making the logical decisions for processing each item.

Of course, there are situations in which one input is concerned with more than one file item, or in which file items are processed when the only "input" is the passage of time, or in which several inputs and/or file items

THE ROUTINE OF BUSINESS-DATA PROCESSING

FIG. 1



are processed to produce a single output. But most business-data processing is concerned with putting each input item into correspondence with a file item to which it refers.

MATCHING INPUT DATA TO FILE DATA

There are two ways to match input data to file data: continuously or in batches. In systems which have a random-access file comprised of magnetic drums, cores, or discs (or even of conventional magnetic tapes if speed is not very important), each input can be accepted as it arises. The corresponding file item, which may be anywhere in the file, is called up (hence the random-access requirement) and the required operation is performed before the next input is accepted. This is continuous, or on-line, processing. Alternatively, the data can be batched, sorted into the same sequence as the tape file data, and processed in sequence. Batch processing uses the tape file more efficiently; there is no unnecessary waiting in going from one item to the next, since each item in the file is read (and processed or altered if necessary) only once.

File processing usually requires file maintenance (adding whole new items, deleting old ones, and handling basic data that do not change regularly or frequently), file updating (adding new data, deleting old data, and changing accumulative data, where all data are inherently transitory in nature and subject to regular and/or frequent change) and file reference (finding wanted data in a file). The addition or deletion of data during file updating or maintenance makes it difficult to use random-access core, drum, or disc files. For this reason, techniques for key-word condensation and probability-weighted address computation are currently under development. In the meantime, random-access files are primarily used where the size and sequence of file items do not change, and where efficiently coded key words are possible, as, for example, in the Teleregister Reservisor system.

Even if file maintenance and file updating did not change the length of filed items or alter their sequence, most magnetic-tape systems do not allow data in the middle of the tape to be changed without destroying the remainder of the tape. And most maintenance and updating do change lengths and sequence. Consequently, tape files are altered by reading the original tape and copying it, with the necessary changes, on a new tape. Since most data processors can read and write tapes simultaneously (usually while computing as well), the recopying procedure does not appreciably hamper a batched process. However, since every item is recopied every time the file is updated, increased emphasis is placed on the accuracy of reading and writing. Many more errors are possible than in a file where inactive items are totally undisturbed while the active items are processed.

Where input data must be processed too rapidly to permit batching, and where the volume of data means that a tape file, rather than a core, drum, or disc file, must be used, recopying the entire file is a major stumbling block. Unless the file is on several reels of tape so that only one tape need be recopied, or unless only file reference, and not maintenance or updating, is wanted, the recopying requirement effectively nullifies any speed increase hoped for in continuous rather than batch processing.

Unit Records, Fields, Keys, and Trailers

The information about each individual employee in a payroll file, about each different stocked material in an inventory file, or about each individual account in any data file is called either an *item* or, more descriptively, a *unit record*. Likewise, the details of any one transaction, event, or change being entered as input constitute an item or unit record, as does any one set of related output data. While there is no precise definition, there is a tendency to use the word *item* in describing inputs or outputs, and *unit record* in referring to basic file data.

A punched card is a unit record limited to 80 (or some other number, depending on the manufacturer) digits or characters of information, one in each column of the card.

A unit record is made up of *fields* of data, a term that reflects the influence of long-standing punched-card nomenclature. Each field contains one quantity, one identifying code number, or one name or other word description, abbreviated or not. Generally, the length of a field in digits or characters is sufficient to handle the longest number or name expected to occur. In standard fixed-word-length computers, the choice of field length is influenced, sometimes quite strongly, by the built-in word length. On the other hand, the tape systems associated with some of the individually-addressable-character (called, less properly, variable-word-length) computers give a free choice of field length; other computers give a truly variable word length, the field length adjusting itself to the actual length of the individual numbers or names. In either case, the internal storage system behaves as a free-field-length and not a variable-field-length device.

A tape file usually consists of many unit records arranged in sequence according to some identifying name or number. The identifying name or number is called the key and occupies one of the fields in the unit record. While there is normally no reason for assigning the first field to the key word, the key usually comes near, if not at the start, of the unit record. Often two or more files of the same unit records, describing different aspects of the same set of accounts, are kept. At the same time, the files may be arranged in different sequences, one field being the key in one set of unit records, and another field the key in another set. Output data are often handled this way if the same data are to be printed and/or summarized in two or more different sequences. Hence, given a unit record, one cannot specify which field contains the key without knowing how the record is to be processed.

When a unit record contains more than 80 characters, it cannot be recorded on one 80-column card. Standard punched-card practice is to use a *trailer* card, or second card following the first and identified by the same key. Tape systems and computers seldom encounter this situation, since the maximum length of unit record that can be handled at one time usually ranges from several hundred to several thousand characters. However, situations often arise in which a unit record should contain a list of indefinite length. For example, in controlling inventory, it is often convenient to know, for each item stocked, the quantity specified in each unfilled order and the due date for each order. Some accounts may have many open orders to list, while others have none, making it extremely wasteful to designate two fields (one for quantity, the other for date) for each of some maximum number of orders in each unit record. Instead, the open orders are often handled as two-field trailer items, carried along behind the main unit record (or *header*) item. Since the number of trailers in a given account record varies, this form of variable record length is achieved through programming.

The Need for Sorting

Sorting data into some predetermined sequence is one of the principal operations in most manual and punched-card data-processing systems. This is primarily a preliminary step leading to filing in batches, but there are other reasons for the operation, too.

Summary distributional information is customarily produced by sorting into the categories to be totalized,

FIG. 2 **FACTORS IN SELECTING A DATA FILE**

I THE VOLUME OF DATA TO BE PROCESSED

A. File Data — number of:
- files
- unit records per file
- trailers per unit record
- digits per unit record
- digits per trailer

B. Input Data — number of:
- items per unit time
- digits (average) per item

C. Output Data — number of:
- reports per unit time
- printed lines per report

II THE NATURE OF THE PROCESSING

A. Level of activity in a unit time — what percentage of all accounts require:
- reference
- updating
- maintenance

B. Complexity of basic processing of an input item with a file record —
- arithmetical operations
- logical operations
- variations and exceptions

C. Input editing required in:
- rearranging fields within an item
- merging several sources into one
- sorting into sequence
- checking the original sequence
- eliminating unwanted or inconsistent data

D. Output editing required in:
- rearranging within an item
- suppressing unwanted zeros
- forma super-imposition
- rearranging into different sequences
- summarizing

III SPEED AND OTHER SPECIAL REQUIREMENTS

A. Tolerable delay between the arrival of data and the complete processing of it (is it minutes or is it days?).

B. Disposition of source documents (must they, like bank checks, be a physical part of the output?).

C. Arrival pattern of the data (is it random or is it periodic?).

D. Erasability required of the file (can a nonerasable, semi-permanent medium like microfilm be used?).

then summarizing, and finally sorting back into sequence again. For example, a company selling 200 different product lines collects sales data in sequence by salesman, but also wishes to know total sales for each product line. Cards describing each sale are sorted by product line, the 200 totals are obtained one at a time, and the cards are resorted into sequence for refiling, or for another distribution (by customer, for instance).

Sorting can even sometimes be used as a substitute for calculation. For example, rather than compute charges for each meter reading, one utility sorts all readings by quantity and applies a precomputed charge to each group of identical readings. The charge tickets must then be resorted into the same alphabetical or geographical sequence as the ledgers.

Thus, the reasons for carefully considering sorting are twofold. First, sorting is often one way, and sometimes the only way, to achieve the desired results. Second, manual sorting and especially punched-card sorting, can be done quickly, easily, and inexpensively by well-established techniques. Electronic data-processing equipment can be built or programmed to sort large volumes of data recorded on reels of magnetic tape. But though it can sort faster than punched card techniques, it is often considerably more expensive.

The difficulties of tape sorting can sometimes be avoided by simply not sorting. Utility charges can be computed rather than looked up. Totals by product lines often can be accumulated by reading the data sequentially only once, and adding each amount into its proper accumulated total, making use of the thousand or more random access storage locations available in most electronic data-processing machines. Frequently, sorting is used to rearrange data for some special report that could be prepared equally well or perhaps better in some more easily produced sequence, if not eliminated entirely. Finally, source data and/or final reports that happen to be prepared on punched cards for other reasons can be sorted on punched-card sorters.

In general, though, punched-card sorters should not always be preferred over tape sorters. It is almost never economical to sort a tape file by punching cards from it, sorting them, and then reconverting the cards to tape. Even with source data originated on punched cards, punched-card sorting will not be the most economical unless card sorting is obviously much cheaper and the sorter and operator are readily available. For one thing, if the data have been previously card-sorted before being recorded on tape, good practice requires that the tape sequence be checked by the computer for mistakes that might have occurred during manual sorting or conversion of cards to tape. In each case, the choice of sorting method depends on the particular application.

The actual cost of sorting data magnetically recorded on tape depends on:
- ► the size and number of items to be sorted
- ► the size and location of the key
- ► the speed and number of available tape drives
- ► the buffering, internal storage capacity, and operating speed of the computer, and
- ► the technique used in sorting

In turn, the choice of technique depends on the characteristics of the items, the keys, the tapes, and the computer.

All business problems involve a data file, but the volume of data, nature of the processing, and special requirements for referring to, updating, and maintaining the file differ for various applications. The more obvious factors involved are listed in Figure 2. Of these, the most crucial in determining the required equipment characteristics are the permissible delay, disposition of the source documents, and the arithmetical and logical versatility required in processing. Short delay requires random-access storage; source document transmission and preservation require mechanical paper-handling gadgetry; computational versatility (either for the single job at hand, or to permit one system to handle several problems) requires stored-program, general-purpose logic.

THE DATA-PROCESSING CHARACTERISTICS OF BUSINESSES

The business world operates by acquiring goods and services, combining these, and disposing of the product, either goods or services, preferably at a profit. Simple as this seems in principle, the details are quite complicated and differ considerably for the individual businesses. Creators of material goods are the *producers* of such things as food, oil, coal, and other mined products, all dependent to some extent on natural resources; and the *manufacturers* of airplanes, automobiles, steel, chemicals, appliances, machines, electron tubes, tools, office machines, forgings, toys, etc., who buy raw material and transform it into finished goods. The *service* businesses are subdivided into such classes as merchandising (the wholesaling and retailing of manufactured goods), public utilities (including communications, transportation, and the distribution of electricity, gas, and water), government (including such truly enormous business activities as those of the U. S. Defense, Treasury, and Post Office departments); finance (such as banks, insurance companies, brokerage firms), and the other professions (engineering, law, medicine, etc.).

Each business differs considerably from every other. But, from the point of view of data to be processed, the differences are not as important as the similarities. Naturally, some industries require more data processing than others. Were it not for governmental requirements, for example, a moderate-sized mine or farm might be run almost without paperwork; on the other hand, paper work is the whole foundation of many financial institutions. Nevertheless, the important differences (or similarities) are not so much those of the industries, but rather of volume of data coming in, volume of data to be filed, types of transactions and number of exceptions, and above all, the time scale on which the processing must be done.

Subscription Files

Some of the biggest and most interesting problems are rather special in nature. For example, fulfillment of the subscription commitments for such national magazines as *Readers Digest*, *Life*, *The Saturday Evening Post*, etc., is a problem involving transcription from a file of several million large unit records, one for each subscriber. The printing problem is severe, but is dwarfed by the problem of maintaining the file in an order that is at once geographical (to meet postal regulations), accessible by expiration date (to permit numerous mailings of promotional literature to nearly expired accounts), and capable of absorbing numerous changes of addresses and of culling out expired subscriptions.

Readers Digest processes and maintains a file of 15 million Addressograph plates; *Time* and *Life* use high-speed stylus printers working from punched cards; the Readers Digest Book Club uses transfer printing (similar to Hectograph and Ditto Liquid duplication) from addresses printed on special punched cards. Similar problems are encountered in direct-mail advertising, capital stock records for distributing dividends and literature to the multitudinous stockholders of each large corporation, etc. Clearly, if the volume is very large a special-purpose device can be used, while for infrequent or low-volume operations a general-purpose computer or conventional punched-card equipment may be more economical.

Tally Devices

Several magnetic drum-storage systems—with direct keyboard interrogation units multiplexed into them—are being used as data files for answering random inquiries. Perhaps the best known is the Reservisor built by Teleregister Corp. for American Airlines. This is a drum that stores the number of available seats on each available flight for several days ahead, plus any holidays close at hand. Located at LaGuardia Airport, the drum can be interrogated from various remote keyboards, the desired flight being keyed in by an edge-punched metal card selected by the inquiring agent. Similar drum tally systems have been built by Teleregister for the Toronto Stock Exchange and for various airlines and railroads, by Electronics Corp. of America for various department stores, and by the ERA Div. of Sperry Rand Corp. for a mail-order house. In these latter cases, the main purpose is to obtain up-to-date usage figures to permit intelligent reordering of stock.

Check Handling

Source documents for bank checking accounts or for gasoline or department-store charge accounts pose a whole new set of problems. Manually operated aids to sorting, such as the widely used IBM proof machines or the newly announced Burroughs Rapid-Sort, are being challenged by semi-automatic systems like the SRI-Bank of America ERMA system. ERMA sorts checks printed on any reasonably sized piece of paper by means of magnetizable spots preprinted on the back to identify the checking account. Prepunched cards are more satisfactory in principle than preprinted forms, but are subject to damage and sometimes meet with considerable customer resistance.

Integrated Data Processing

Even when the source document need not go through a lengthy chain of processes, the transmitting problem is still difficult. Punched tape—which can be prepared as a by-product of invoices, department store sales slips, etc., and which can be transmitted either by mail or over conventional teletype systems—is being touted as a common-language medium. Its current popularity in this function has made punched-tape devices almost synonymous with *integrated data processing*, or IDP. The term IDP is applied to any system that transmits data from one office to another in a machine-readable form, thereby reducing the number of times any datum must be read and transcribed manually.

THE BASIC PROBLEMS OF BUSINESS

In addition to those special cases outlined above, four other data-processing problems are present in some degree in every sizable business:

- payroll — paying for employee services
- payables — paying for goods obtained from suppliers
- receivables — collecting for products or services sold
- inventory—maintaining a record of available raw materials, finished goods, or salable services; and furnishing data on replenishment needs.

Of these, payroll and inventory are the most interesting since each is a large and important problem in most businesses and each has many facets not obvious at first glance. Payroll, for instance, represents an accounting function in which the output one day does not appreciably affect the behavior of the system and hence the next day's input; inventory control, on the other hand, can involve decision-making and thereby the use of the data processor as part of a control system.

Inventory Control

Inventory control is not one problem, but several. Whether the product is automobiles, hardware, food, space on an airline, or money (as in a bank), business management must know the following three things about its inventory:

- the quantity on hand (to know whether a given order can be filled)
- when to place an order to replenish the stock of each given material
- how to order

Three other factors are useful as measures of effectiveness, sources of worry, and bases for calculating profits and taxes. These are:

- the value of the inventory on hand at any given moment
- the value of all issues and/or receipts in a given period, and
- the extent of pilferage or other mysterious disappearance

In most businesses, value is obtained by taking periodic physical inventory. Often the business shuts down for two or three days once a year, and every item in stock is counted. Valuations and discrepancies are then computed during the next several months. The question of whether a demand can be filled is answered by examining the shelf on which stock is kept. Whether stock needs to be replenished is likewise determined by comparing balance on hand with some reorder level, discussed below under Inventory Management.

Inventory Tally

It is sometimes desirable, and in some cases mandatory, that a running record of stock on hand be maintained. Purveyors of style and seasonal goods, for example, must know the movement of each stock item from day to day so that they can restock those in demand while the demand still lasts. And any service industry operating on a by-appointment basis, such as the airlines or Pullman Co., must, because of the very nature of its business, keep a tally of its inventory.

Inventory tallying is then, like payroll, an accounting operation. However, it differs from payroll in one important respect—the allowable time delay between the occurrence of an event and the processing of the information. In dealing with a weekly payroll, for example, there is usually a two- or three-day permissible delay between the end of a week and the day the pay checks must be ready, and there is generally no need to process any data concerning a given week until the end of the week. Thus, payroll lends itself to being processed in batches once a pay period. Where inventory is tallied for purely accounting purposes, long delays are also permissible. But most data-processing inventory problems arise because the tallying is being done to permit interrogation or control or both. Then the time element becomes critical. For example, the delay between the sale of an airline seat and the recording in the inventory tally system must be very small—preferably not more than a few seconds.

Saving up all the data for a week, a day, or even an hour and processing it in a batch is not always feasible, since it may not meet requirements. Wherever people are involved (and they usually are in business problems), delays of a few hours are often excessive, while delays of a few seconds are usually acceptable. Designers of elevators, telephones, and other service systems find 10 to 60 sec a maximum tolerable delay. In dealing with certain types of customers or with members of the same organization, circumstances often permit a delay of several hours or even several days without serious inconvenience. Since high-speed systems cost more, it is important to determine the permissible delay and the dollar value of decreased delays.

Inventory Management

A properly managed inventory control system provides material when it is needed at the least possible cost. Too much inventory costs money (return on investment, cost of insurance, storage space charges, allowance for obsolescence, etc.), and not enough inventory costs money also (increased likelihood of an out-of-stock condition with attendant expediting expense, delay, loss of sale, loss of future sales, etc.). The theory of inventory management is not yet perfected.

Determining when and what are somewhat interrelated questions that are usually dealt with separately. Both depend on a prediction of future requirements. Multiplying the estimated stock required each day by the number of days it normally takes to get delivery on an item gives a reorder level—but makes no allowance for uncertainty about predicted requirements or predicted delivery time. Thus a safety stock is usually added to the reorder level. At present there is no satisfactory or widely accepted procedure for predicting requirements or for determining optimum safety stock. There is, however, a widely used formula for determining the quantity that should be ordered to replenish stock. This economic lot size, derived to minimize the total operating cost (carrying cost plus reordering costs), is

$$\sqrt{\frac{\text{quant. used (units/yr)} \times \text{ordering \& setup cost(\$)}}{\text{unit cost (\$/unit)} \times \text{carrying cost rate (\$/\$/yr)}}}$$

Despite the lack of a complete theory of inventory management, there is a great potential savings in replacing present hit-or-miss manual systems by even a partially satisfactory system carried out reliably, inexpensively, and expeditiously on automatic data-processing equipment.

Inventory-Data Processing

Inventory, like payroll and almost all other business problems, involves processing input data against a file, updating the file, performing certain computations, making certain decisions, and producing certain reports. Since payroll problems are discussed in the next section, it would be interesting at this point to compare the characteristics of inventory-data and payroll-data processing.

- The on-line nature of inventory-data processing frequently precludes batching (while payroll is inherently a batch process).
- When batching is possible—whether the data is collected and processed every minute, every hour, or every day—relatively few stock accounts are likely to be affected by a batch of inputs (while in payroll most employee accounts are effected by each batch.)
- Inventory management is more complex than payroll, while inventory tallying by itself is much simpler.
- While payroll is a clearly defined problem, differing little from company to company, inventory control is imperfectly defined or understood and its requirements differ widely.

The regular inputs for inventory-data processing consist of notification of sale or issue of some quantity of a specified item, receipt of some amount of replenishing stock, placement of an order, correction of on-hand balance to compensate for lost material, and inquiries as to balance on hand or on order. When inventory management is involved, the system must deal with such variables as unit cost, setup cost, lead time, etc. As always, there is the question of entering new accounts and deleting old ones.

The file, in the case of tallying alone, contains only the balance on hand and perhaps the balance on order. When management is involved, the above-mentioned factors must be added to data about past usage, etc.

The outputs may be merely the answers to the questions asked, plus a list of low balances or a list of all balances. When management is involved, lists of amounts to be ordered, orders to be expedited, and overdue orders may also be among the outputs. Reported less frequently are such routine accounting data as dollar value of

stock on hand for each stock item, dollar value issued in a given period, dollar value of open orders, dollar value of reported inventory shortages and overages, etc.

Payroll

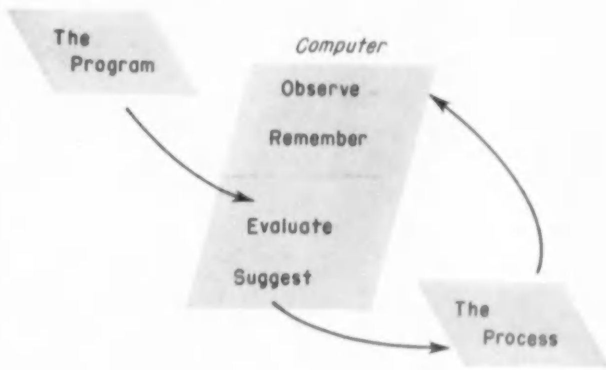
The routine data sources for payroll are time cards showing total time worked (for salaried and regular hourly employees, these are often replaced by an absence report), and job tickets showing time spent on different jobs (these do not occur in every payroll; they are used for cost accounting and to determine incentive-type bonuses often paid production workers). More sporadic are changes in basic file data, arising each time an employee is added, given a new job classification or a raise, is married, has children, moves, changes his payroll deduction, or quits (not to mention the myriad of other changes).

The basic data contained in the file includes home address, age, sex, seniority status, etc., as well as name, social security number, employee number, number of tax exemptions, job classification, deductions (for union dues, bonds, stocks, medical insurance, life insurance, pension, credit union, company store purchases, local taxes, garnishments, etc.), and pay rate. In addition to this basic data, which changes irregularly and (hopefully) infrequently, there is a collection of current totals for tax accounting and other purposes. These include such year-to-date figures as total salary or wages paid, income tax withheld, and social security withheld; and perhaps balances due or paid on other taxes, stocks, bonds, and noncollects (an unwithheld deduction to be collected later from an employee who commits himself to a deduction but doesn't earn enough during some pay period to cover it).

There are two major areas in the data-processing problem: the calculation of gross pay from the time documents, and the calculation of net pay from the given gross. Basically, gross pay equals hours worked times rate per hour. But there are other factors: overtime allowances paid at time-and-a-half, double, or triple time, depending on hours worked in each 24-hour period, in each week, on holidays, and the like; incentive bonuses based on hours worked, group or individual norms, and pay rate (or the fraction thereof subject to incentive); and any possible complications, such as when an employee works on several jobs at different base rates and different incentive factors within one week. Net pay is, of course, gross pay minus various percentage, fixed, and occa-

THE OFFICE, AND THE MANAGERS, ARE PART OF A FEEDBACK LOOP

"A business system consists of a large number of low frequency components (people)."



THE COMPUTER IN THE FEEDBACK LOOP

"Industrial control is concerned with devices, while business control is concerned with people"

"Whether one deals in automobiles, hardware, food, space on an airplane, or money in a bank, one has an inventory...."

sional deductions for taxes, dues, insurance, company store, etc.

The primary outputs are pay checks or pay envelopes (in the latter case, the system must also "denominate" the payroll, accumulating totals showing how many coins and bills of each denomination are required to fill all the pay envelopes). Journal and ledger data are obtained, but may be kept on tape for further processing and never printed out in the original form.

Trivial as payroll processing may seem, don't underestimate the length of the required computer program. The first few applications of a large computing system—the UNIVAC—to weekly payrolls in plants employing 5,000 to 20,000 hourly paid workers required computer programs of from 15,000 to 150,000 steps. The situation is typical of many business-data-processing problems. The principles are simple enough; but requirements set by law, convention, whim, or tradition, and not readily susceptible to standardization make exception the rule and personalities a hurdle.

DATA PROCESSING IN INSURANCE AND GOVERNMENT

No general discussion of business applications would be complete without some mention of the two largest categories of record keeping—insurance and government. The large, varied, active files of data that are inherently part of life or casualty insurance were the incentive for much of the business-computer pioneering in the United States. Metropolitan Life and The Prudential were leaders in this work, to which Sun Life of Canada, Franklin Life, and others contributed. Rather surprisingly, the first real application of a general-purpose computer to business was made by J. Lyons and Co., which operates a chain of hotels, restaurants, and tea shops in England. They built their own computer, LEO (Lyons Electronic Office), basing it on Cambridge University's EDSAC.

The earliest sponsor of business-computer development was the Bureau of the Census, for whom the first UNIVAC was built. In fact, it was a former Census employee, Herman Hollerith, who in 1889 originated the first punched-card data-processing equipment, largely with census problems in mind. This bureau is but one of many U. S. Government agencies with truly staggering data-processing problems. Internal revenue, social security, government bonds, and Defense Department activities are larger than any commercial problem by at least a factor of ten and often a thousand. Inventory controlled by the Air Force exceeds $30 billion, more than 30 times that of the General Motors Corp. Records of U. S. bond owners number 60 billion, more than 2,000 times the number of Metropolitan Life policyholders, and so it goes.

Most business computers today are being used for routine record keeping. It is widely realized that improved efficiency through better forecasting, scheduling, and planning offers hope of far greater return than does any reduction in clerical cost. As a spokesman for scientific management put it, "We are in business to make money, not to save it." But these new possibilities, opened up by the recent trend toward using mathematics in business (operations research) and by the faster, cheaper computing facilities of the electronic digital computer, are far from being thoroughly explored. Future business-data processing will offer more data, better analyzed, and available in time to be an aid in planning.

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CHARLES W. ADAMS

Last January Charles W. Adams went down to Caracas, Venezuela, to join the Comptroller's Dept. of Creole Petroleum Corp., an affiliate of Standard Oil of New Jersey. He completed the present article before he left for South America and while serving a one-year term on the staff of the director of methods and procedures of Westinghouse Electric Corp. This appointment followed a period of eight years as a member of MIT's Digital Computer Laboratory, where Mr. Adams had been a programmer, logical designer, and group leader in charge of engineering and scientific computations. During that period at MIT, he earned an SB in physics and an SM in mathematics and taught computer programming and logic as an assistant professor of digital computation in the EE Dept. He is 31 years old.

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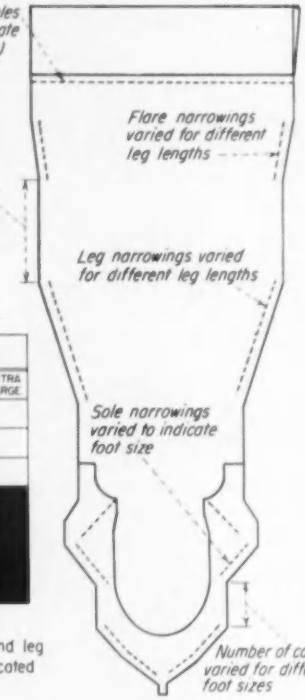
Nylon Stockings Tape-Programmed to the Wearer

CHARLES FEGLEY, Laureldale, Pa.



	Leg Length			
FOOT SIZE	SMALL	MED.	LARGE	EXTRA LARGE
8	■	■		
8½	■	■		
9	■	■	■	
9½	■	■	■	■
10		■	■	■
10½			■	■
11			■	■

Table showing foot sizes and leg lengths manufactured, indicated by filled in blocks

VARIATIONS POSSIBLE IN A STOCKING BLANK

Full-fashioned nylons are knitted by a machine controlled by chain motion and control shafts. These devices, depending upon the type of machine and style of stocking being knit, can accomplish up to 50 different machine functions—a necessary flexibility, since variation in two or more of these functions is required to produce different sizes in any style being run.

The sketch of the full-fashioned stocking blank shows some of the changes that are possible on the versatile machine. Length is controlled by the number of courses knit (in full-fashioned knitting a course is one complete row of loops across the width of the fabric). Width is controlled by narrowing (the act of transferring selvedge loops toward the fabric center to reduce width and produce a form-fitting garment when the selvedges are seamed together). Besides these changes, some manufacturers will mark leg length with a picot or loose course in the after-welt or welt (the upper part of the stocking furnishing the garter portion, usually made of different material).

How It's Been Done

The conventional way to effect these size changes is by repositioning chain buttons on the chain or by setting a device which, when tripped, would automatically stop the main chain, add the number of courses, then restart the chain. Actually, while this device does add courses, it will not change any of the other functions. Changing from one size to another still requires from 10 to 30 minutes down time. And the many changes produce mistakes.

How It Will Be Done

The new size changing method described uses photoelectric circuits operated by a punched tape and does the job in a few seconds. The cost of the tape, control box, and accessories is relatively small compared to their mechanical counterpart—the cost of the chain and buttons arrangement can run as high as $500.

Both chain motion and control shafts in the knitting machine are indexed by a common cam shaft and controlled by the main or master chain. The new size changing system is also controlled by the main chain motion, as shown in Figure 1. The special unit for adding courses to the stocking is shown in Figure 2. Both mechanical arrangements are described in detail under the illustrations.

Figures 3 and 4 show the photoelectric control box and the punched tape. The tape illustrated has 20 rows for punched holes. One row is used to start the main chain and stop the size changer. The next two rows are for the loose courses and the next six rows operate as a course counter. The remaining rows are used for narrowings.

By placing a control card between the light source and the photocell, the latter can be actuated by both tape and card. The punched card will block off all rows of holes in the tape except those in alignment with its own holes. Hence the arrangement makes it possible to produce almost an infinite number of sizes with one tape.

Tabbing an Action

Let us use the loose course as an example of how varied action can occur. The tape has two rows set aside for loose course, but it can be made to produce four different designs. The sample punch shown in Figure 4 indicates that the tape has one hole in row one of the loose course and two in the other. By inserting a card with no holes in it, nothing will be produced. However, inserting a card with two holes in it will expose two rows and produce three loose courses. One or two loose courses can be produced by inserting a card with only one hole in it—to expose one or the other row on the tape.

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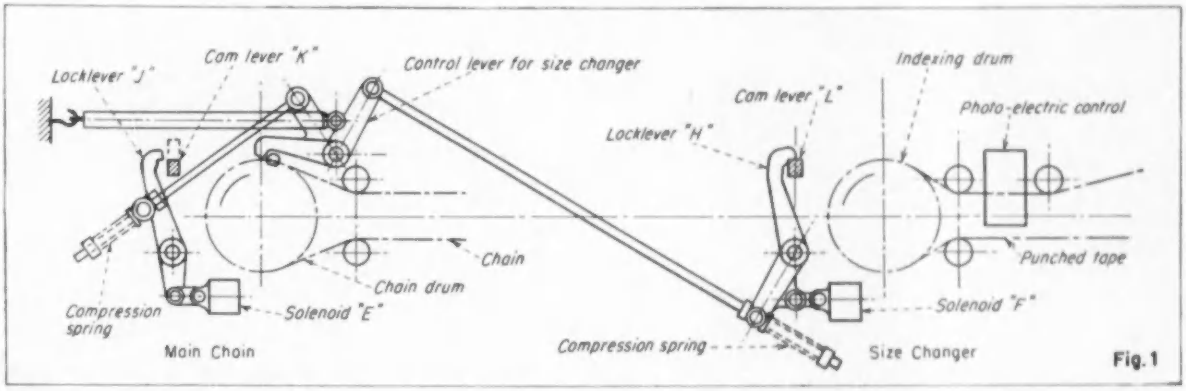


FIG. 1. HOW THE SIZE CHANGER IS CONTROLLED BY MAIN CHAIN MOTION

As a chain button is indexed under the size changer control lever on the main chain, it releases the cam lever "L", and at the same time locks the button under the control lever by locking the cam lever "K", making the main chain inoperative. The cam levers "K" and "L" operate their respective pawl levers, which through pawls and ratchets index their unit. With its cam lever free, the size changer will now index and will continue to index until a hole in the stop row is moved in line with the light source. The photocell will now energize solenoid "E", which releases lock lever "J" and permits cam lever "K" to operate. The main chain will index the chain button from under the control lever, forcing lock lever "H" over cam lever "L" and at the same time mechanically releasing lock lever "J". On the same course, the hole will be indexed, closing off the light falling on the photocell.

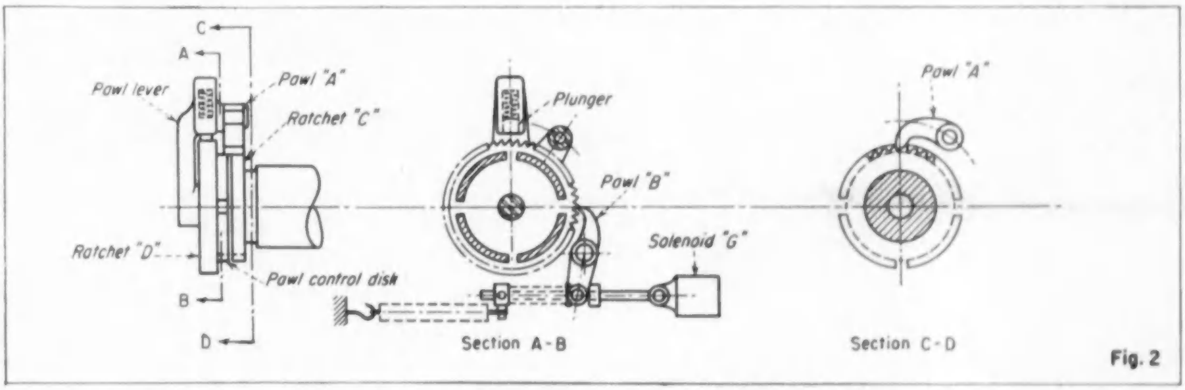


FIG. 2. HOW COURSES ARE ADDED TO THE STOCKING

The pawl lever, with its plunger engaged in ratchet "D", will oscillate the ratchet as the pawl lever is moved by its cam lever. Fixed to ratchet "D" is a pawl control disc which has slots cut into it. Through these slots pawl "A" is able to engage ratchet "C", since pawl "A" and its control disc (fastened to ratchet "D") oscillate together. Pawl "A" will index ratchet "C" which will index the tape drum until a hole is indexed between the light source and photo-cell for counting; at which time solenoid "G" will be energized, causing pawl "B" to engage ratchet "D". As the pawl lever is moved back, pawl "B" will prevent the return of ratchet "D"; this will force pawl "A" up on the pawl control disc and prevent it from engaging ratchet "C", which will stop the tape from indexing. The ratchet will be indexed a preset number of courses, determined by the number of teeth covered by the control disc. When the count is complete the pawl lever will move back, pawl "A" will fall in the slot and index the tape, which will, in turn, index the hole putting off the light falling on the photocell. This frees ratchet "D".

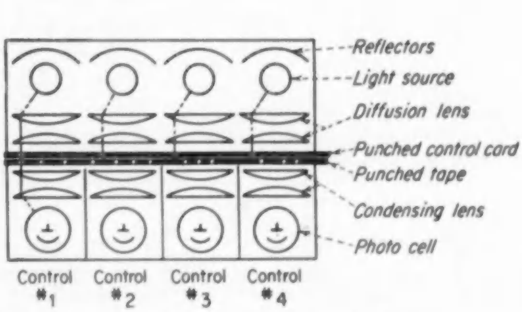


FIG. 3. Schematic diagram of the control box.

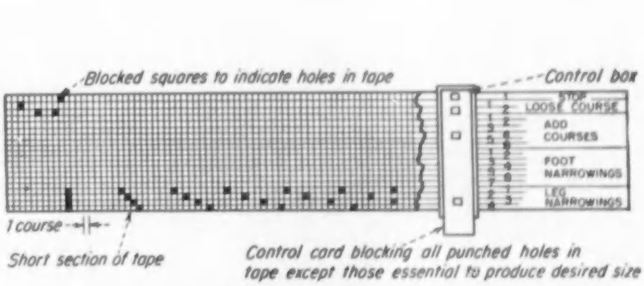
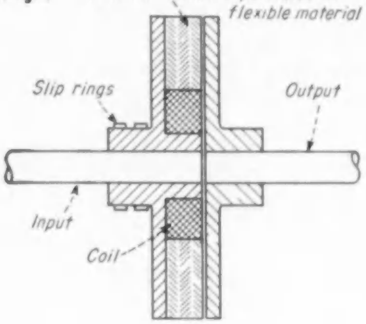
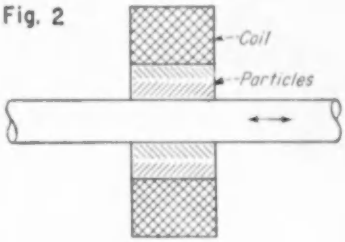
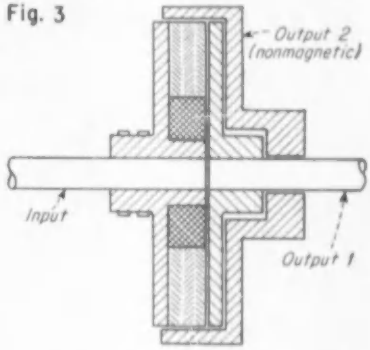


FIG. 4. Schematic diagram of punch tape and control card.

Magnetized Rubber Grips in Clutch







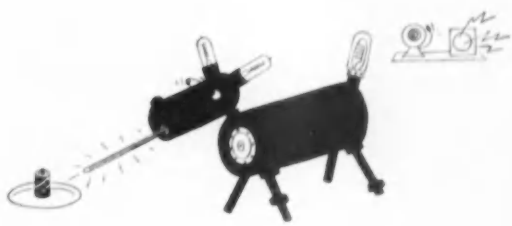
Shortly after our New Products editor remarked on the ingenious design of a new magnetic clutch (CtE, March, p. 116), Industrial Controls Corp. of Chattanooga, Tenn., passed along a patent application for the one shown here. The item is not in production, although the maker has an operating model. A type of magnetic particle clutch, it displays an operating principle substantially different from anything going under that name.

The magnetic particles between the driving and driven discs, Figure 1, are imbedded in rubber or other flexible material, each particle at an angle, as shown. The flux path of the coil tends to straighten out the individual particles, forcing the material in which they are imbedded to expand in the direction of the space between the discs. If the particles are long enough (i.e., rod-shaped) each will contact the discs, cocking between them to increase the driving force.

The basic principle is not limited to torque transmission. Figure 2 shows how the lineal motion of a shaft can be arrested by the same approach.

Another unique feature is the way the particles are magnetized. It will be seen from Figure 3 that an electromagnetic field of one polarity will cause expansion along the axis of the clutch's shaft and that a field of the opposite polarity will cause expansion radially, driving the clutch's nonmagnetic housing rather than the output disc. Here, then, are the makings of a bi-directional clutch—an item in demand for clutch servos.

Here's A Self-Optimizing Rover



Last April (p. 55), when Mel Fusfeld covered control in The Netherlands, Rover was left behind. He's just padded in:

"Professor C. J. Verhagen's Control and Instrument Laboratory at Delft University is really going to the dogs. It all started with a decision to construct a small demonstration unit to show how an electronic assembly could be made to exhibit conditioned reflexes. Someone came up with the bright idea that since it was basically Pavlov's principles that they were trying to illustrate, why not build the model in the form of a dog? When finished, the electronic pooch had a tail and two ears made of vacuum tubes and a long, special neon tube for a tongue. The unit worked like this: the length of the ionized gas column in the neon tube (or tongue) represents the degree of salivation and is the reflex being conditioned. The reward or 'meat' is represented by a small dry-cell. A bell and buzzer are placed near the dog. Now if the dog is fed without sounding either the bell or the buzzer, the actuation of these signals at some other time will not stimulate salivation. But if the bell is sounded when the dog is fed it will soon respond, through association, with salivation—even if later on no feeding accompanies the bell. However, if the bell is sounded frequently enough without feeding, the dog will stop salivating (lack of reinforcement). Now the dog, if trained on the bell, will not respond to the buzzer, and vice versa. It can be trained to respond to both bell and buzzer. But if trained on only one, and both signals are made, there will be no response (inhibition). So we have here the most elementary form of learning—the conditioned reflex, where we act automatically in response to some condition (or signal) because there is an association between the signal and our action. No toy this, but simply another step in the long quest for the instrument man's Golden Fleece—the self-optimizing controller."

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VARIATIONS OF **PRESSURE, VOLUME** temperature, fluid flow, expansion, absorption, adsorption, chemical alterations, altitude, vacuum, etc.

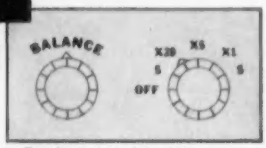
Provides

ONE MICRON OF MERCURY **RESOLUTION** at any ambient pressure up to 2 atmospheres. 7.5 volts output available for recording at full scale differential pressure of 1 mm of mercury.

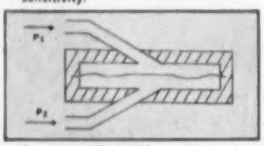
High Sensitivity Micro-Differential PRESSURE METER

Completely Self-Contained

no accessories required

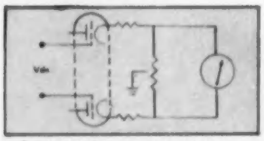


Two-knob control for balance, . . . sensitivity.

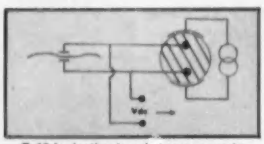


Pressure differential moves beryllium-copper diaphragm.

Utilizes the T-42 IONIZATION TRANSDUCER



Output applied to cathode follower to drive meter.



T-42 Ionization trandsducer converts motion into electrical signal.

This unusually simple pressure instrument is completely self contained. It requires no special accessories, additional equipment or trained personnel for operation. Merely plug this compact instrument (only 5" x 5" x 10") into the 115 V, 60 cy. line and in 2 minutes it is ready for use. Two knob control . . . for balance and sensitivity.

It is an extremely versatile and truly valuable accessory for any laboratory.

Details on this new micro-sensitive meter are in Instrument Data Sheet 303-1, available upon request to Technical Literature Section.

decker AVIATION CORPORATION

1361 Frankford Ave., Philadelphia 25, Pa., PHONE GArfield 5-2300

Programmed Checker Plots Transducer Calibration Error

MAX MILLER, G. M. Giannini & Co., Inc.

Pneumatic and electric circuit changes are programmed automatically to record errors in total resistance and resistance function in two-potentiometer pressure transducers.

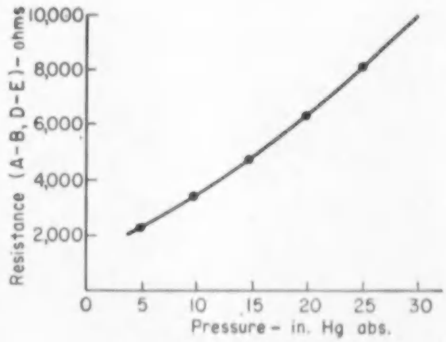


FIG. 1. Calibration curve of typical potentiometer pressure transducer.

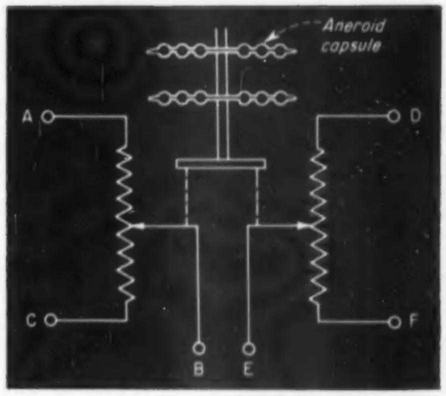


FIG. 2. Schematic diagram of pressure transducer with two potentiometers.

The calibration of potentiometer pressure transducers has generally been checked by piecework hand operations: a technician sets a pressure, using needle valves and manometers, and makes resistance readings on a bridge. This introduces human errors, giving, for the same transducer and the same measuring system, different results for different operators. Large-scale production now has made possible the development of an automatic system for checking the calibration of pressure transducers.

The particular transducer which this system was designed to check has two potentiometers actuated by a common aneroid element. It has a pressure range from 30 in. Hg to 4 in. Hg. Its output must be an empirical function, such that for each of five specific input pressures the resistance between one end of the resistance coil and the brush equals some nominal value within a given tolerance. This function is a calibration curve like that of Figure 1. Figure 2 is a schematic diagram of the transducer.

This transducer was chosen as the first unit for which the system was to be used because (1) the unit is in quantity production, (2) the output is nonlinear with respect to the input, and (3) the calibration must use both pressure and vacuum. It was felt that with this combination of requirements for the system, the resulting design would be most adaptable to use with other transducers.

System operation

Figure 3 is a block diagram for the system, which operates as follows: the operator initiates the program action and the program unit simultaneously transmits a pulse to the time delay, starts the chart drive on the recorder, and connects the comparison circuit so that it will measure the total resistance of one of the two potentiometers contained in the transducer.

After a 5-sec time delay to allow for recording, the time-delay unit transmits a program pulse to the program unit, which then moves on to the next portion of the cycle: the measurement of the instrument calibration deviations from nominal as a function of pressure. To accomplish this, the program unit connects the comparison circuit to the transducer and standard instrument and transmits a pulse to the pneumatic control. This closes the pneumatic circuit to atmospheric pressure and opens it to the pressure source.

Within the pneumatic circuit the pressure begins to rise. Pressure changes in the system are made slower than the response of the transducer to eliminate dynamic errors. When the pressure has reached a predetermined upper limit, the standard instrument signals the program unit, causing it to close off the pressure source and open the pneumatic system to a vacuum source. As the pressure drops in the pneumatic system and passes five predetermined calibration pressure levels, the standard instrument transmits program pulses to the program unit and triggers an event marker in the recorder.

When the pressure has reached a lower predetermined limit, the standard instrument again transmits a program signal to the program unit, which simultaneously initiates a time delay of approximately 25 sec, closes off the vacuum source, and opens the pneumatic system to vent. After this delay, during which the pneumatic system bleeds to atmospheric pressure through the vent, the time-delay unit transmits a program pulse back to

***EXTERNAL FIELD REDUCTION OF 10 TO 1** is measured, above, using a magnetic pickup coil and a meter. The housing cover is removed exposing the terminal board. This new stabilizer, like all Sola Constant Voltage Transformers, is a static-magnetic regulator, has no moving parts and requires no manual adjustments or maintenance. It provides automatic, instantaneous voltage regulation within ±1%, even with primary voltage swings of ±15%.*

New Sola Constant Voltage Transformer Reduces External Field by 90%

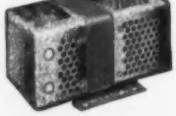
An improved Sola Constant Voltage Transformer design retains all the advantages of the Sola CV principle while providing a 90% reduction in external field and up to 53% lighter weight.

In applications employing "magnetic field-sensitive" electronic equipment, such as high-gain audio circuits, the new Sola CV design offers important advantages. Cathode ray tubes—high-gain amplifiers—microwave plumbing—may be mounted close to the transformer; usually magnetic shields may be eliminated.

The new housing has a smooth overall contour which minimizes dust accumulation. It is finished in attractive gray hammerloid.

The new Standard Type Sola CV transformer is available in 3 capacities—250, 500, and 1000va. For specific advice on your particular application, contact your Sola representative listed below.

SOLA *Constant Voltage* **TRANSFORMERS**



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4633 W. 16th Street
Chicago 50, Illinois

CONSTANT VOLTAGE TRANSFORMERS for Regulation of Electronic and Electrical Equipment • **LIGHTING TRANSFORMERS** for All Types of Fluorescent and Mercury Vapor Lamps. • **SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414** • *NEW YORK 35: 103 E. 125th St., TRafalgar 6-6464 • PHILADELPHIA: Commercial Trust Bldg., Rittenhouse 6-4988 • BOSTON: 272 Centre Street, Newton 58, Mass., Bigelow 4-3354 • CLEVELAND 15: 1836 Euclid Ave., PRospect 1-6400 • KANSAS CITY 2, MO.: 406 W. 34th St., Jefferson 4382 • LOS ANGELES 23: 3138 E. Olympic Blvd., ANgelus 9-9431 • TORONTO 17, ONTARIO: 102 Laird Drive, Mayfair 4554 • Representatives in Other Principal Cities*

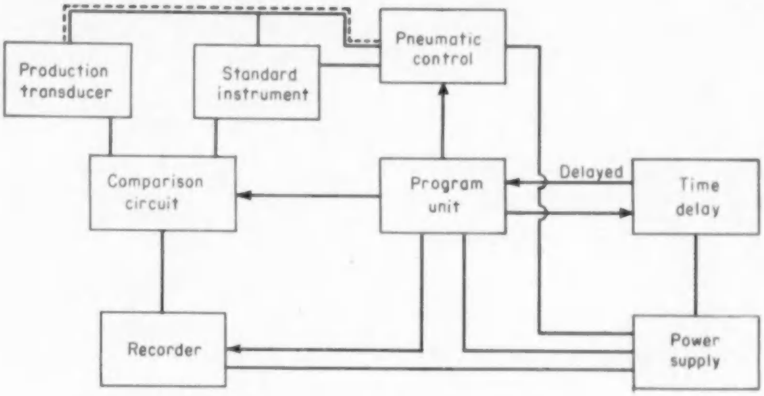


FIG. 3. Block diagram of automatic calibration checking system.

the program unit and the program unit advances to its third sequence position.

In the third sequence position the program unit transmits a control pulse to the comparison circuit. This transfers the connections from one potentiometer in the transducer to the other and makes the connections necessary to measure the total resistance of this second transducer potentiometer. At the same time the program unit transmits a control pulse to the time-delay circuit and initiates the 5-sec time delay during which the error in total resistance of the second potentiometer is recorded. At the end of the time delay, the time-delay unit again transmits a program pulse to the program unit and the pressure cycle repeats itself.

The final program pulse from the standard instrument at the end of the pressure cycle initiates a 25-sec delay, at the end of which the time-delay unit program pulse to the program unit deenergizes the circuit and sets up the initial system conditions in preparation for another run on another instrument.

Comparison and recording

As might be gathered from the block diagram, the measured output from the pressure transducer is compared to an output from a standard instrument. Figure 4 illustrates how these instruments are connected in series as one leg of a Wheatstone bridge. If all the legs of the bridge are identical, then the bridge is balanced and the bridge output voltage is zero.

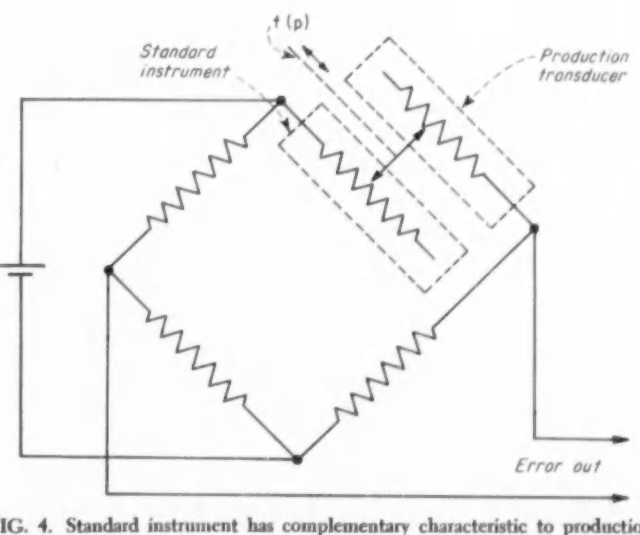


FIG. 4. Standard instrument has complementary characteristic to production transducer. Bridge output is zero throughout range for perfect transducer.

The calibration curve for the pressure transducer is an empirical function, defined by smoothly fairing five input versus output values. The calibration curve of the standard instrument complements the nominal calibration curve of the transducer so that, when summed with the output of the pressure transducer, the combined output is a constant. This maintains a nominal bridge balance throughout the pressure range. In addition, the resolution, linearity, hysteresis, and transient response characteristics of the standard instrument are of such a nature that they introduce little or no error into the operating system.

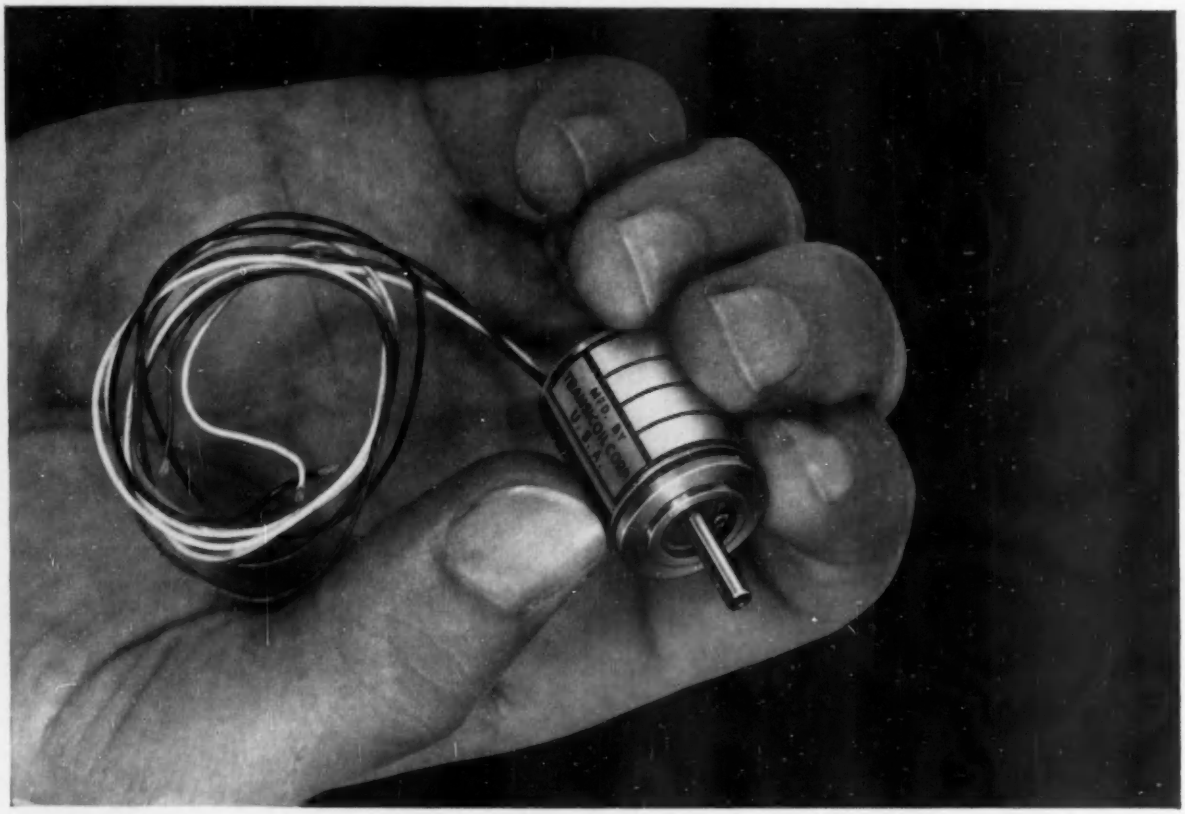
Output and data reduction

Thus, the comparison-circuit output voltage is proportional in magnitude and sense to the departure of the pressure transducer from its nominal output value. This output, when applied to the input terminals of a self-balancing potentiometer recorder, appears as a departure of the pen position from the nominal zero base line. The bridge sensitivity is set so that the full-scale pen travel is approximately equal to or slightly greater than the maximum allowable tolerance deviation from null for the pressure transducer. The standard instrument is compensated to maintain long-time stability as the complement of the nominal calibration curve.

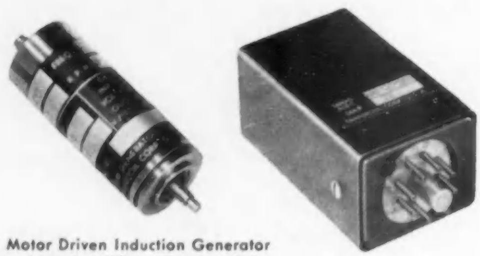
A mask of the physical proportions of the calibration tolerance envelope is superposed on the recorder chart. If any portion of the pen trace lies outside this tolerance envelope, the transducer on test is rejected.

Tapping the standard

As has been indicated, the program forcing functions come from three sources: (1) the operator, (2) the time-delay circuits, and (3) the standard instrument. The problem of the program portion of the standard instrument is one of precise commutation at given pressure levels. A high-resolution commutator was built into the instrument by winding a standard linear resistance coil and splitting the resistance wire along one side of the coil. The commutator wiper is a standard potentiometer brush and the commutator contacts are tap brushes resting on the coil at given distances from the end determined as a function of pressure. This gives an adjustable commutator with adequate resolution but with rather limited current-carrying capacity. The limit on the current-carrying capacity is circumvented by operating the commutator at low signal levels and using the commutator outputs to trigger thyratron relays.



NEW Size 8 servo combination rivals Size 9 performance



Size 8 Motor Driven Induction Generator and Transistor Amplifier. All units of the Size 8 system have been designed for maximum performance in minimum space.

Here, no bigger than your thumb, is the smallest *practical* servo control motor currently produced. Combined with Transicoil's new Size 8 motor driven induction generator, and powered by a new completely-transistorized servo amplifier, this motor offers you the unusually high torque-to-inertia ratio of 28,000 radians/sec^2.

Compared with a Size 9 control motor—until now, the smallest practical unit available—Transicoil's new Size 8 measures only 0.75 inches in diameter, 10% smaller, and weighs only 1.4 oz., 40% lighter. Yet it operates on standard voltages from 26 to 52 volts, and 52 volts with center tap, at 400 cps, permitting push-pull transistor application.

Hence, just as Transicoil's introduction of plate to plate wiring eliminated the transformer, once necessary in servo systems, the Size 8 units and transistor amplifiers mark another milestone in miniaturization.

This is just one more example of how Transicoil can solve your control problems whether they involve miniaturization or control complexity, and go on to manufacture systems and components of the utmost precision and accuracy. You pay only for results—on a fixed fee basis for equipment delivered and performing properly.

Technical data on the new Size 8 combination and the transistorized amplifier is yours for the asking. But you'll end up with a better system if you write outlining your servo control problem.

TRANSICOIL CORPORATION

Worcester, Montgomery County · Pennsylvania

Hydraulic Valves can have Low Tolerances *and* High Stability

The usual servo-controlled valve requires exceptionally close tolerance manufacture to give stable operation. A simple change in valve design eliminates most of the sources of error, and reduces required accuracy of manufacture.

FRANKLIN F. OFFNER
Offner Electronics Inc.

Regulating systems frequently employ servo-operated hydraulic valves, in which the controlled fluid is the same as working medium of the servo system. A typical example of such a system is the fuel control of aircraft turbine engines. Here, a pilot valve controlled by electronic or mechanical means adjusts the position of the fuel valve to hold the desired engine speed.

Precise operation of such systems usually requires that a fixed position of the pilot valve correspond to the rest position of the servo valve. A typical system is illustrated in Figure 1. The inlet pressure to the valve, P_a, and the discharge pressure, P_d, are the working pressures for the pilot valve. When the stem of the pilot valve is so set that servo pressure, P_1, plus the spring pressure, P_s, above the valve piston, is equal to P_a, the valve will be stationary. That is,

$$P_1 + P_s = P_a \qquad (1)$$

Even for a stationary piston position, there will be continual flow through the pilot valve. With a valve as shown in Figure 1, there will necessarily be continual leakage past the throttle piston. This must be compensated by flow through the pilot valve. But even if there were no leakage past the throttle piston, there would still be flow through the pilot valve because it is impossible to manufacture a pilot valve that will seal off completely in its neutral position. Especially in a sensitive servo system, positive lap may not be employed, as it would give rise to a "deadband" with consequent stability problems. Thus considerable "zero-point" flow must be anticipated; just how much will depend on manufacturing tolerances.

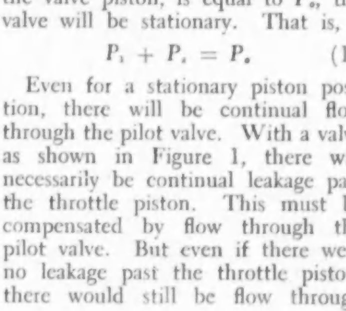


Fig. 1

If the spring has a very low rate, P_s may, as a first approximation, be considered constant. Then Equation 1 shows that the drop across the leakage path in the pilot valve between the high pressure line and the servo line is constant. On the other hand, the discharge pressure P_d will vary over wide limits, usually from near P_a to practically zero. The drop across the pilot valve leakage path from servo to low pressure is $P_1 - P_d$; thus this too will vary widely. It is apparent that the two leakage paths must continually change with P_d to maintain the two leakage flows equal, a requirement if there is no leakage past the servo piston (as is possible with a sylphon-sealed valve); or to maintain a fixed differential of leakage, a requirement if leakage past the piston must be considered. Thus the "neutral" position of the pilot valve will continually change with discharge pressure. This may have undesired results. In a turbine speed control, for example, it may give rise to a change in speed with altitude—"speed droop".

A simple design change

A rather simple change in design of the system shown in Figure 1 eliminates the inherent errors described above, and at the same time permits much wider manufacturing tolerances. The revised system is shown in Figure 2. Whereas the valve of Figure 1 meters only on the discharge side, that of Figure 2 meters on both the inlet and discharge. (Although single

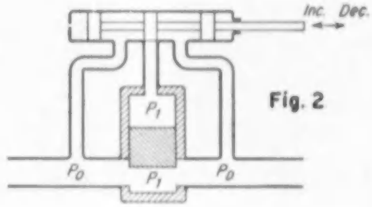


Fig. 2

inlet and discharge orifices are shown here, in practice the valve is made with two balanced orifices to avoid side forces.) If the two orifices are identical in shape and flow characteristics, the drop across the two will be equal; the pressure below the valve piston will thus be midway between P_a and P_d; i.e.,

$$P_1 = (P_a - P_d)/2 \qquad (2)$$

The valve will now remain stationary if the pressure above it is also equal to P_1. This pressure will be maintained if the two leakage paths in the pilot valve remain equal, because the two working pressure differences remain equal: $P_a - P_1 = P_1 - P_d$.

This equality remains true, despite leakage paths around the valve piston. Since there is no pressure difference across the piston at rest, there will be no leakage across it even though clearances be made rather wide.

Thus, stationary servo-valve position corresponds to a fixed position of the pilot valve, and is independent of inlet pressure, discharge pressure, or valve position, and droop characteristics of the system are eliminated.

The theory of the valve has been borne out in practice. Where the original valve design required micro-inch accuracies to obtain the necessary stability for turbine engine control, the new design actually permitted clearances to be measured in thousandths of an inch, with better stability of performance.

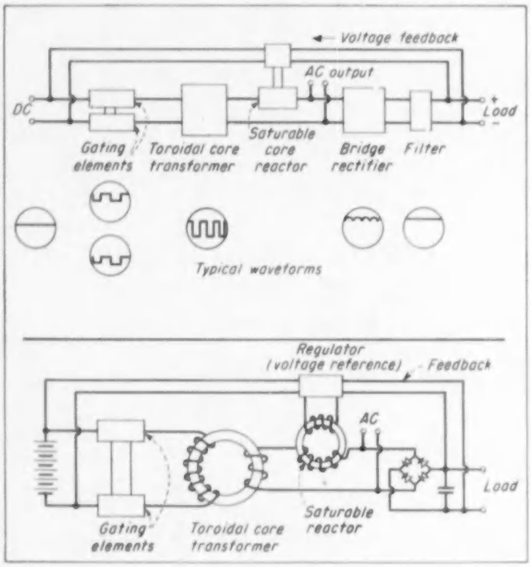
NEW PRODUCTS

LISTING IN GROUPS

SOLID-STATE circuit transforms dc.

In goes low voltage dc, out comes high voltage dc from a new series of standard and special model solid state circuits. Inside, semi-conductors and saturable reactors chop the input into square waves, transform it to a higher voltage, then rectify it. Sizes range from ¾ to 1,000 watts. To estimate the bulk of one of the circuits for a particular application, allow approximately 1 cu in. per watt at 6-volt input. As the arrangement is current-sensitive, higher or lower voltages have a proportional influence on the size (e.i., 12-volt input cuts the size in half, 24-volt input cuts it to one-fourth). Inputs range from 1.5 to 60 volts, and outputs from 1.2 to 20,000 volts. Some of the encapsulated units are sold without the final rectifier stage, to provide 60- or 400-cps square-wave or sine-wave ac power. Regulation to within 0.1 per cent can be attained, and ripple is normally held to within 0.003 per cent.—The Interelectronics Corp., 2432 Grand Concourse, New York 58, N. Y.

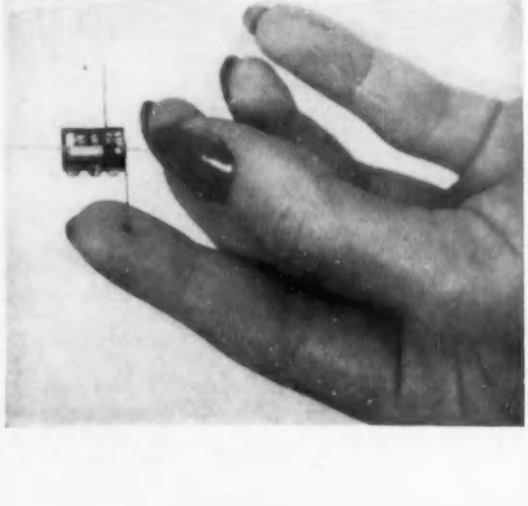
Circle No. 1 on reply card



SUPERSMALL transistor for amplifiers.

Philco claims 20 of its latest PNP transistors can be placed on a dime. The M-1 alloy-junction transistor is now going into production for the guided-missile, hearing-aid, and portable-radio market. Typical of the sort of assemblies made possible by the tiny welded-seal device is the 70-db gain amplifier (power gain of 10 million) shown here. The maker claims it will tolerate 20,000 g vibrations. The germanium wafer in the little component is about the size of a pinhead. Leads are soldered to a dot of indium on each face of the wafer.—Government & Industrial Div. of Philco Corp., 4700 Wissahickon Ave., Philadelphia, Pa.

Circle No. 2 on reply card



IN NEXT MONTH'S ISSUE . . . The facts on Ampex's new modular magnetic-recording components for all phases of data handling and signals from dc to 100 kc. Tape speeds are from $1\frac{7}{8}$ to 60 ips. A complete 14-track system occupies only $73\frac{1}{2}$ in. of rack height.

NEW SIMPLICITY for Cypac components.

Approximately a year after they were first introduced, Cypac switching-circuit components are being offered in plug-in form for increased mechanical ruggedness and ease of use. The basic approach is the same: the use of magnetic and semiconductor elements in control circuits normally constructed with relays. Plug-in simplicity in the new presentation adds a few new twists. Each of the 3-by-2-by-2-in. cartridges has terminals on both upper and lower faces. Phasing of each unit (one of the important variables in the magnetic-circuit design) is reversed simply by turning it around and plugging the other end in. The logic function of each module is printed on its case to ease circuit assembly.–Westinghouse Electric Corp., 401 Liberty Ave., Box 2278, Pittsburgh 30, Pa.

Circle No. 3 on reply card

COMPUTER gets differential analyzer.

The inclusion of a digital differential analyzer with their general-purpose computer moves Bendix to call the new product an all-purpose computer. The differential analyzer is said to simplify programming procedure for the solution of linear and nonlinear differential equations, and a library of specialized subroutines is available to enable inexperienced personnel to prepare problems. An electric typewriter provides direct input and output from the machine. Input or output operations can be initiated by a single command for as many as 108 words and there is no halt of calculation operations. Auxiliary equipment includes up to four magnetic tape units, each capable of 300,000-word storage, graph plotters and followers, etc.–Bendix Computer Div. of Bendix Aviation Corp., 5630 Arbor Vitae St., Los Angeles 45, Calif.

Circle No. 4 on reply card

NEW FEATURES dress up ALWAC.

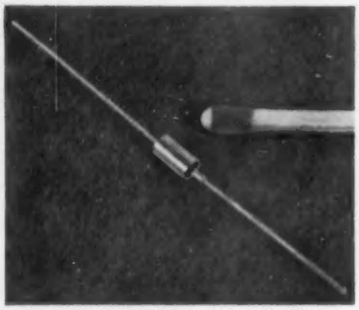
The ALWAC III-E, a low-cost, medium-speed digital computer, is now in quantity production with a group of new improvements. The machine can repeat sequences on numbers stored in different parts of the memory without changing the form of the instruction. Only one program step is needed to set the special editing register which modifies the address, saving the time formerly required to change instructions in a sequence before using them again. The same register acts as an automatic tally for repetitive sequences.

Another new feature: the machine picks up two instructions simultaneously, permitting the second instruction to be carried out as soon as the first is finished without a second reference to the drum.–Logistics Research, Inc., Redondo Beach, Calif.

Circle No. 5 on reply card

NEW PRODUCTS

CONTROL COMPONENTS



MINIATURE CAPACITORS

Although only 1/8 in. in diam and 1/4 in. long, the little capacitor shown here is rated at 12 mfd. The new tantalum devices are said to contain a solid dry electrolyte and to represent a **"major breakthrough"** in the miniature capacitor field. Their stability is said to rate with the best oil-paper capacitors rather than with the 10-times-larger paste electrolytics. A temperature range of from minus 132 to plus 185 deg F will make only a 5 per cent change in capacitance value, says the maker. It's called the type 150D.—Sprague Electric Co., 97 Marshall St., North Adams, Mass.

Circle No. 6 on reply card

RANDOM PULSE GENERATOR

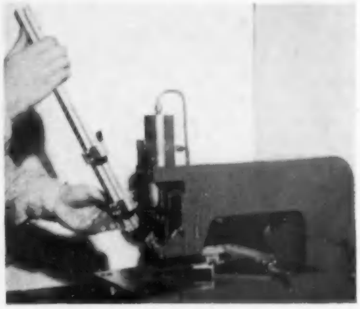
Completely transistorized, the neat random pulse generator shown here delivers pulses at a **controlled rate from 10 to 1,000 pps.** Complete with its own batteries, the little instrument has an output of from 5 mv to 5 volts from 100 ohms.—Universal Atomics Corp., 19 E. 48th St., New York 17, N. Y.

Circle No. 7 on reply card

VOLTAGE REGULATOR

An improved twin triode for voltage regulator service **dissipates 13 watts per plate.** Called the Type 5998, it is recommended in place of the Type 6AS7G or the 6080. There is no grid current in the 5998, which has a transconductance of 14,000 micromhos, and a mu of 5.5.—Chatham Electronics, Livingston, N. J.

Circle No. 8 on reply card



PRINTED CIRCUIT ASSEMBLER

The fully automatic Autofab printed circuit component assembler has been compacted and redesigned for semi-automatic operation. The procedure for changing fixture dimensions in the sewing-machine-sized Autofab Short Run Assembly Machine has been simplified to where a production run of a few dozen boards is economical. The maker says that the single-head hand-fed tool can be modified in less than a minute for different components and boards. Leads are trimmed before insertion and crimped to hold each component in place. The new tool is powered by 115-vac and 60-lb air pressure, and handles cylindrical components ranging from 3/8 to 1 11/16 in. long and from 1/8 to 11/16 in. in diam.—Mechanical Div. of General Mills, Inc., 1620 Central Ave., Minneapolis 13, Minn.

Circle No. 9 on reply card

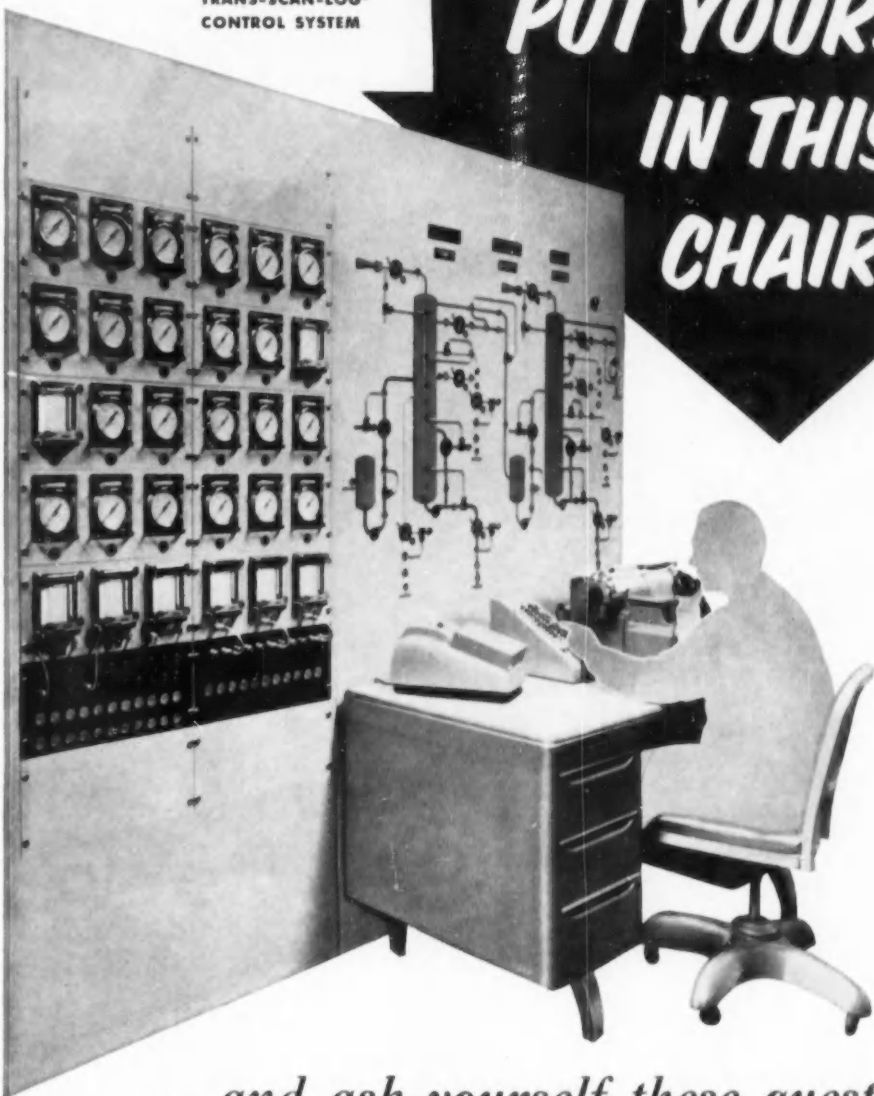
FM SIGNAL GENERATOR

For calibrating FM receivers, a new signal generator offers output ranges of 0 to 30 kc and 0 to 250 kc through its band of 27 to 230 mc. Frequency deviation accuracy is said to be better than 5 per cent of full scale at 1,000 cps.—New London Instrument Co., Inc., 35 Union St., New London, Conn.

Circle No. 10 on reply card

TAYLOR
TRANS-SCAN-LOG*
CONTROL SYSTEM

PUT YOURSELF IN THIS CHAIR



. . . and ask yourself these questions

Is scanning and logging, as I understand it, economically justified?

Perhaps not, if you're thinking just of mechanical logging of all variables, which gives little more than an accurate historical record of what has happened. But the new Taylor TRANS-SCAN-LOG System makes the operator more than a score-keeper. It enables him to instantly *visualize, evaluate* and *act upon* every processing irregularity as it occurs — without leaving his desk in front of the panel.

What effect would the TRANS-SCAN-LOG System have on my control room space and operator requirements?

It will take approximately 60% of the space normally required by a standard graphic panel *without* scanning and logging. The compactness of this "intelligence center" enables operator to supervise a greater percentage of the process. Because the scanning and logging equipment is an integral part of the process control, one operator can identify and correct any off-normal condition, as well as having a continuous trend record.

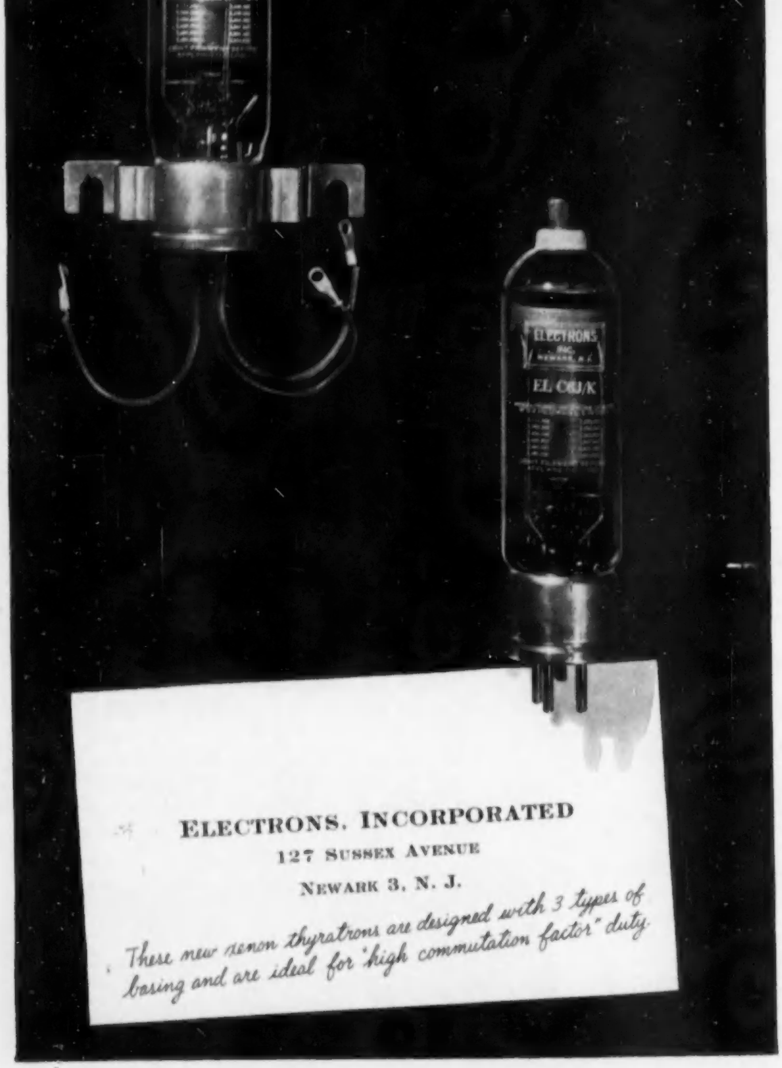
Where can I see this unit in operation?

We cordially invite you to come to Rochester to see this complete data collecting system in operation, because we believe that its many unique features *do* make it economically justified.

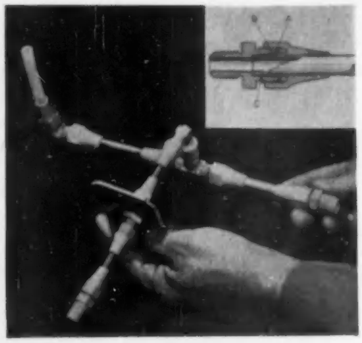
Your Taylor Field Engineer will be glad to make the necessary arrangements. In the meantime, write for **Bulletin 98268.** Taylor Instrument Companies, Rochester, N.Y., or Toronto, Canada.

*Trade Mark

Taylor Instruments
MEAN ACCURACY FIRST



NEW PRODUCTS



NYLON FITTINGS
A line of tube fittings ranging from $\frac{1}{16}$ to $\frac{1}{2}$ in. features a design which **requires only one part for each tube joined.** Temperatures from minus 70 to plus 295 deg F and pressures to 500 psi are withstood by the Zytel Miracle Fittings.—The Jaco Mfg. Co., P. O. Box 2659, Cleveland 7, Ohio

Circle No. 11 on reply card

TUBE FITTINGS
New fittings for copper or aluminum hydraulic tubing are attached simply by inserting the tubing and tightening a nut. **Sizes range from $\frac{1}{8}$ to $\frac{1}{2}$ in. in brass.**—Fort Wayne Div. of The Weatherhead Co., Fort Wayne, Ind.

Circle No. 12 on reply card

IMPROVED RESINS
A new family of potting compounds is offered for encapsulating circuits and components.

▶ Randac R-4060 is a casting resin. It keeps its characteristics up to 276 deg F, and sets in from 3 to 6 hours. It can be poured at room temperature,

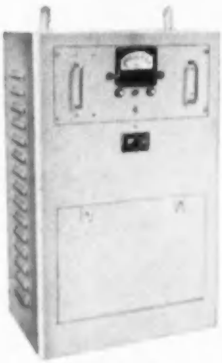
TAKE A HARD LOOK

at how V. V. T.* can be causing trouble

*Varying Voltage Troubles masquerade under many names — and some you will never hear about because they are so common they become "standard operating procedure".

You'll find that a STABILINE® Automatic Voltage Regulator can end many of your production, maintenance and inspection "bugs". STABILINES maintain constant voltage to voltage-sensitive equipment. They are a sure cure for costly varying voltage troubles that can cause burned out motors and lamps . . . production rejects due to sluggish solenoids . . . process recycling caused by out-of-phase control equipment . . . electronic tube failure — just to name a few.

There is a STABILINE to meet your automatic voltage regulation requirements. Three types are offered: Type EM (Electro-Mechanical), Type IE (Instantaneous-Electronic) and Type TM (Tubeless Magnetic). Numerous standard models are available in capacities from ¼ to 100 KVA.



STABILINE TYPE EM6220Y. Holds output voltage constant . . . ends the troubles caused by voltage variations.

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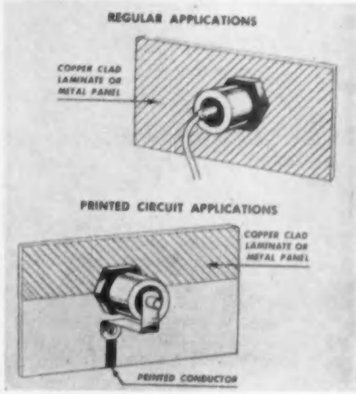
and a clear version can be obtained.
► R-4059 is designed for room-temperature application and is semi-flexible in the cured state.
► R-4053 is thermoplastic until cured. This means that it can be "molded" without a mold, or used in dip-coated applications.—Mitchell-Rand Insulation Co., Inc., 57 Murray St., New York 7, N. Y.

Circle No. 13 on reply card



PRINTED CIRCUIT INDICATORS

The good-looking little indicator lamps shown here are designed for use with printed-circuit-wired indicator panels. They mount on 7/16 centers, enabling 250 to be placed on a 6-by-6-in. panel. Bulbs for the tiny lights work on voltages ranging from 1.3 to 28.—Circon Component Co., 175 Raymer St., Northridge, Calif.

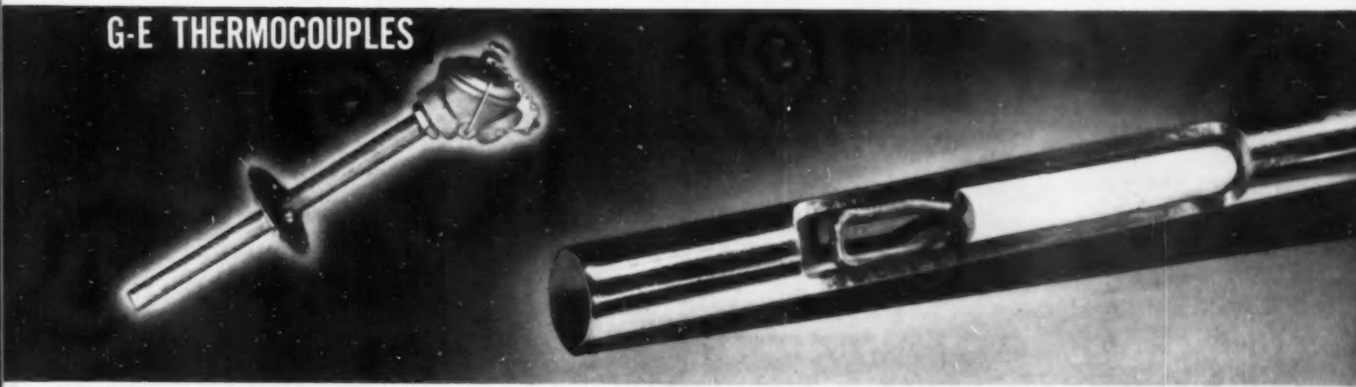
Circle No. 14 on reply card

RUGGEDIZED THYRATRON

A new type 2050W thyratron is offered for industrial use. Anode voltage rating is 1,300, current 100 ma. Design features include silicone rubber

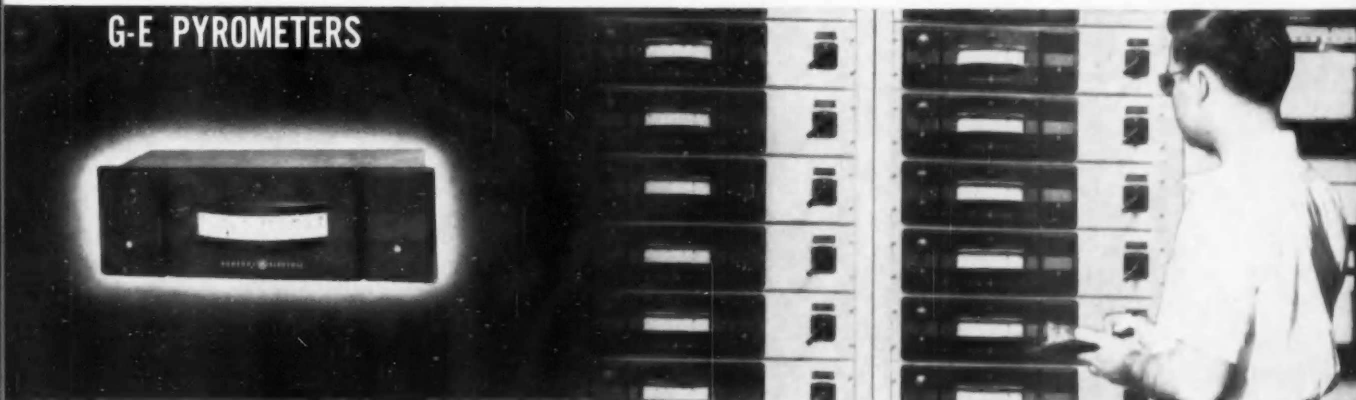
Now Get Precise Heat Process Control

G-E THERMOCOUPLES



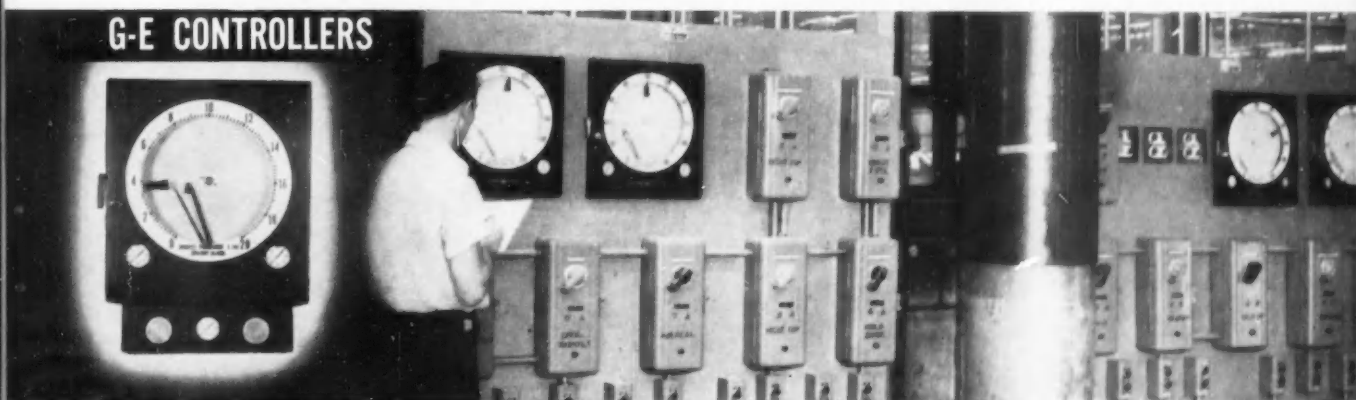
DEPENDABLE DETECTION of heat process temperatures can help you avoid costly production losses. General Electric's complete line of thermocouples, wire and accessories includes custom-tailored primary detection elements for nearly every heat process application. Butt-welded junctions in G-E thermocouples (shown above) respond faster to temperature changes than conventional twisted types. General Electric offers fast shipment of thermocouple wire from factory stocks.

G-E PYROMETERS



PRECISE INDICATION of temperatures can give you close quality control of products in your heat processes. G-E indicating and controlling pyrometers offer a low-cost way to maintain precise temperatures despite changes in voltage or ambient. You are assured of precision control with complete repeatability, and high sensitivity that initiates control action when temperature changes equal as little as 1/10 of 1% of full scale. Seven-inch non-parallax scales are easy to read.

G-E CONTROLLERS



RECORDED CONTROL of heat in your processes can give you truly continuous product quality. G-E potentiometric recorder controllers provide long-term accuracy, precise measurement and continuous dependable control. Features are continuous standardization, automatic break-circuit arrangement, and reduced maintenance by elimination of slidewire and batteries. Both pneumatic and electric control models are available for your individual applications.

FOR FURTHER INFORMATION on G-E thermocouples, pyrometers, and potentiometric recorder-controllers, contact your nearest G-E Apparatus Sales Office or write Section 587-5, General Electric Company, Schenectady 5, N. Y.

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GENERAL ELECTRIC

between base and bulb and double mica mount supports.—Chatham Electronics, Livingston, N. J.

Circle No. 15 on reply card

TOROID TRANSFORMERS

Input impedances up to 370 k with little phase shift are said to be typical for a new line of tiny transformers offering ratios from 100:1 to 1:1:1.—Arnold Magnetics Co., 5962 Smiley Dr., Culver City, Calif.

Circle No. 16 on reply card

CONTROL THYRATRON

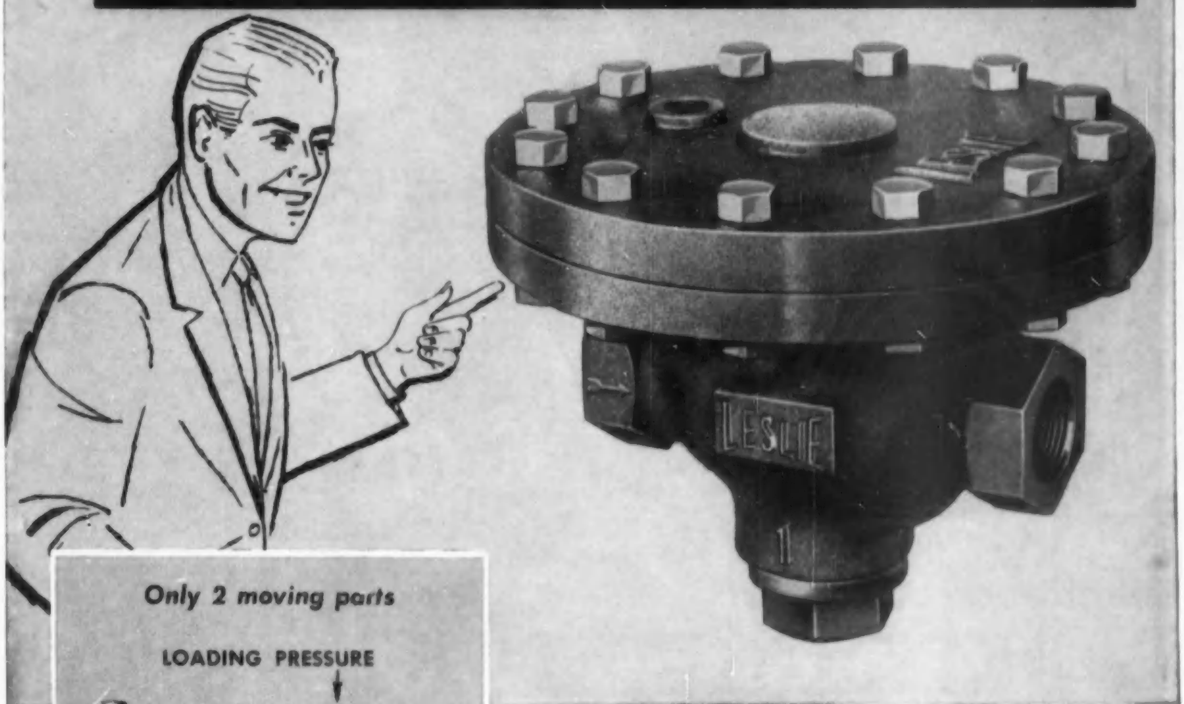
Three new 6.4-amp negative control thyratrons, GL-6807, GL-6808, and GL-6809, have maximum negative control **grid voltage before conduction of minus 250 and during conduction minus 10.** The new tubes carry pin, flexible lead, and spade lug terminals. They all operate at lower temperatures than the GL-5545, which they supersede.—Tube Dept. of General Electric Co., Schenectady 5, N. Y.

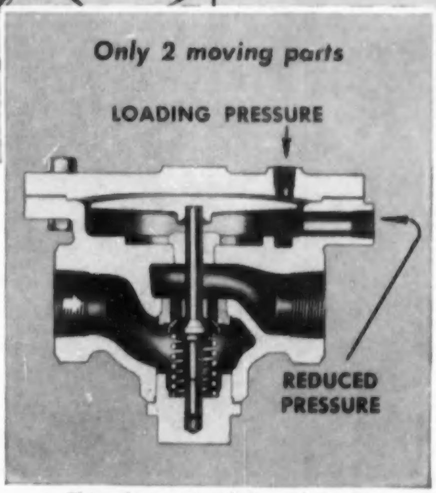
Circle No. 17 on reply card

PRINTED CIRCUIT KIT

Printed circuits, dials, nameplates, or greeting cards are possible applications of this neat silk-screen kit. They say that a resist pattern (a pattern that resists etching acid) can be **economically run in batches from 3 to 10,000** or more (although we suspect that the contents of the kit will give out before then). $27 will buy resist ink, squeege, and du Pont screen process film and chemicals, and in-

Now Leslie brings you this New NO MAINTENANCE* Reducing Valve





This shows simplicity of Leslie Class G-1 pressure reducing valve.

HERE IS AN AMAZINGLY SIMPLE air loaded, diaphragm operated, pressure reducing valve that is virtually maintenance-free for steam heat or process steam application.

Only two moving parts and no seals, no stuffing boxes, no small dirt-catching parts — practically nothing can get out of order! And a stainless steel hardened main valve with highly polished finish minimizes wear.

This new Leslie valve instantly feels the effect of any flow change and responds to changes as small as 0.1 psi. It can be adjusted easily from minimum to maximum of reduced pressure range from a remote point, even a thousand or more feet away.

This valve is used in steam process and heating lines. And, its uses are unlimited for any steam reductions within body material limits (250 psi, 450°F).

Ask your Leslie engineer to tell you more about this amazing valve. He's listed in your classified directory under "Valves" or "Regulators".

****guaranteed no maintenance for 3 years.***

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LESLIE CO., 211 GRANT AVENUE, LYNDHURST, NEW JERSEY

CONTROLLED QUALITY MEANS QUALITY CONTROLS

struction booklets, all in a plastic box. If you can photograph it, this setup will enable you to silk screen it, says the maker.—Techniques, Inc., 178 Central Ave., Hackensack, N. J.

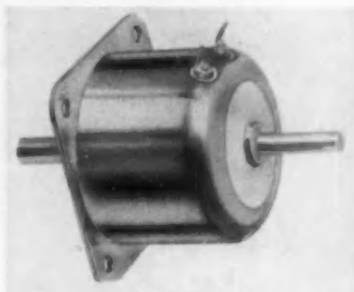
Circle No. 18 on reply card

TORQUE SOURCES

SMALL 60-CPS SERVOMOTOR

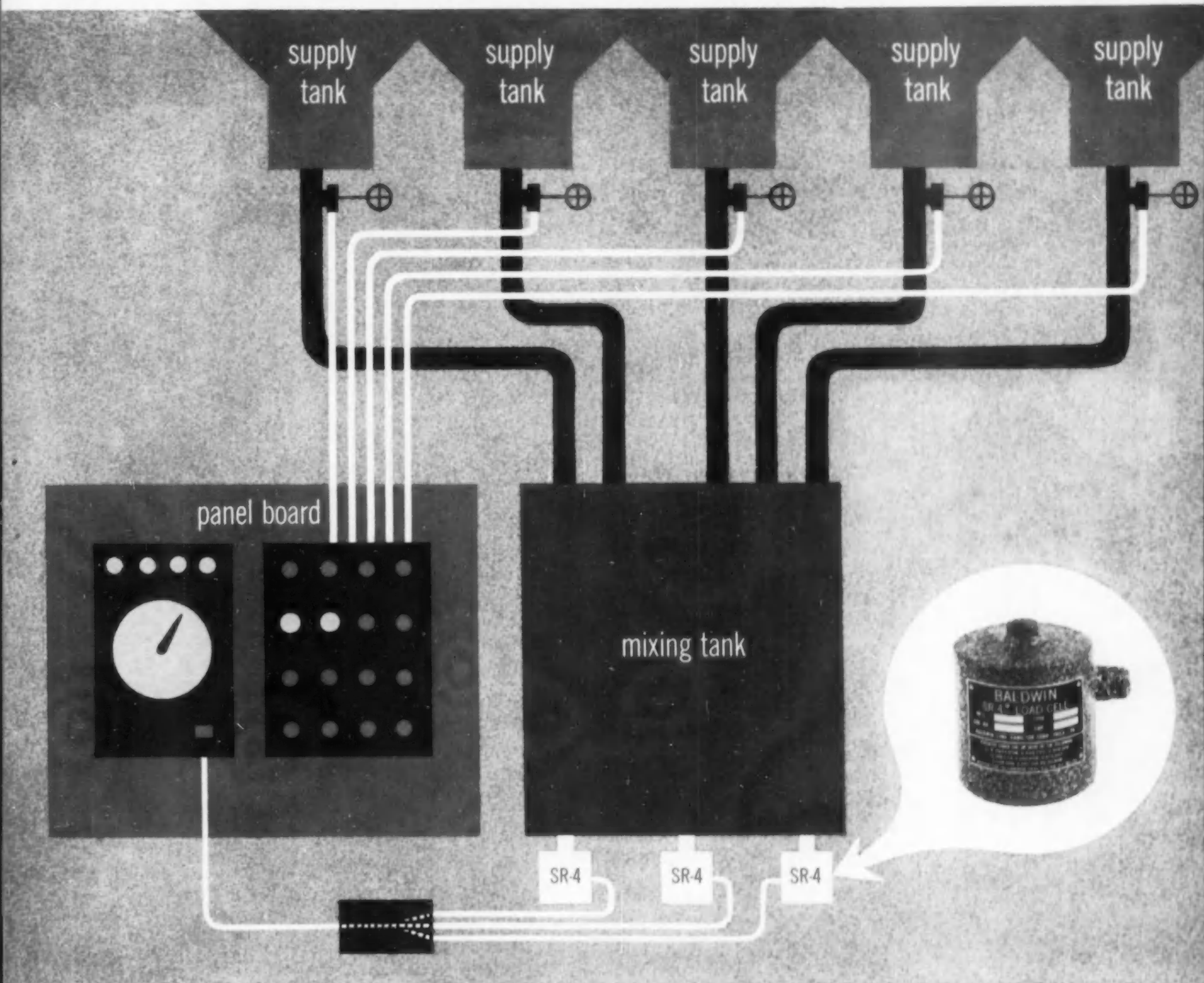
A case $1\frac{1}{4}$ in. in diam houses a new 60-cycle servomotor sold with either hysteresis or induction-type rotors. The maker sells **standard gear trains to go with them.**—Globe Industries, Inc., 1784 Stanley Ave., Dayton, Ohio.

Circle No. 19 on reply card



ROTARY SOLENOID

Any degree of shaft travel, from 5 to 60 deg cw or cww, in increments as small as 1 deg, plus the availability of any desired torque curve, are two major design features of a new line of rotary solenoids. **Outputs up to 15 lb-in.** are provided by the $1\frac{13}{16}$-in.-in-diam devices. Shaft is free of axial motion, and rated for a million cycles. Intermittent- and continuous-duty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models for most dc voltages are available.—Pacific Solenoids, Inc., 208 Standard St., El Segundo, Calif.

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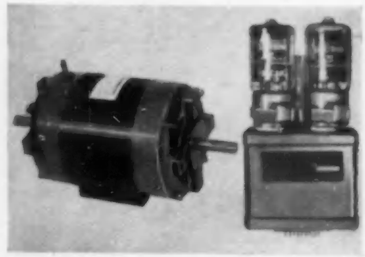


CONTROLLED SPEED

The new products shown here **deliver constant rpm within 1 per cent** at any selected speed from 30 to 16,000 rpm, regardless of load and wide fluctuations of line voltage and frequency. The motor is a 400-cycle induction type, delivering about 5 oz.-in. torque. —WacLine, Inc., 35 S. St. Clair St., Dayton 2, Ohio.

Circle No. 21 on reply card

SERVOMOTOR-TACH

A top speed of 19,600 cpm at a temperature of 140 deg C is one claim for a new servomotor-generator combination. It uses a two-phase two-pole size-11 motor with drag-cup-type generator. Here are some of its specs:

- ▶ 2.85-gm-cm² inertia
- ▶ 1.03-in.-in-diam max
- ▶ 4.6-oz weight
- ▶ 26-volt 400-cps input
- ▶ generator linear to within 1 per cent to 8,000 rpm.

It's called the type MG-3088.—Avionic Div. of John Oster Mfg. Co., Racine, Wis.

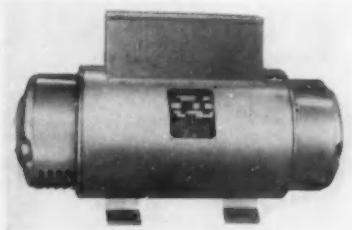
Circle No. 22 on reply card

1½-IN.-IN-DIAM DC MOTORS

A line of new miniature dc motors can be supplied with series and split windings (the latter for reversibility). The maker has **gear reducers, governors,**

and brakes to fit if desired.—Globe Industries, Inc., 1784 Stanley Ave., Dayton 4, Ohio.

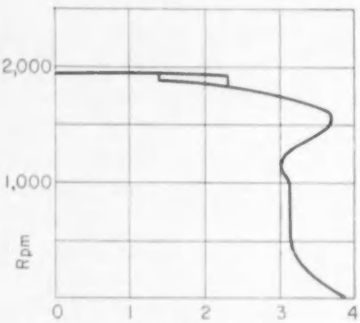
Circle No. 23 on reply card



400-CPS MOTOR-ALTERNATOR

A source of 400 cps, three-phase power (from 500 watts to 5 kw) for those with 60-cycle mains is the object of a new line of motor alternators. Their magnetic-amplifier-type voltage regulator will hold **output to within 2 per cent**, with recovery time near ¼ sec. Frequency regulation is 406 to 418 cycles.—The Hertner Electric Co., 12690 Elmwood Ave., Cleveland, Ohio.

Circle No. 24 on reply card



SYNDUCTION MOTOR

A new type of electric motor **combines features of the standard induction and synchronous motors.** Size ranges are from ¼ to 40 hp. Frequencies ranging from 10 to 300 cycles have been developed. Near synchronous speeds the new motors exhibit 175 to 200 per cent of rated torque. One application for this species of motor is in systems requiring a large number of motors held in perfect synchronism. They use no slip rings, commutators, or separate source of dc excitation.—Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

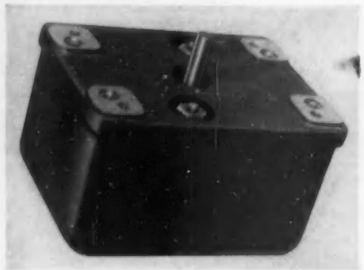
Circle No. 25 on reply card

NEW PRODUCTS

DC TIMING MOTORS

A standard escapement allows a dc motor power to travel through a specified distance in a specified time, thereby attaining overall timing accuracy to within 0.1 per cent, regardless of load variations or line variations of 20 per cent. The little instruments weigh only 7.5 oz and are offered with a variety of gear boxes.—The A. W. Haydon Co., Waterbury, Conn.

Circle No. 26 on reply card



ROTARY SOLENOIDS

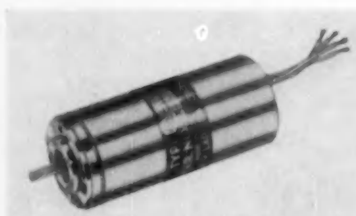
Compact casing keynotes design of a new series of rotary solenoids. Continuous and intermittent 115-vac models with **rotations ranging from 20 to 60 deg** offer torques in the range of 12 in.-lbs. All models in the new 400 series are totally enclosed—Leetronics, Inc., 30 Main St., Brooklyn, N. Y.

Circle No. 27 on reply card

SMALL MOTOR

About the size of a grapefruit, a new appliance motor offers 1,550 rpm at from 1/250 to 1/15 hp quietly and economically, says the maker.—Redmond Co., Inc., Owosso, Mich.

Circle No. 28 on reply card



SIZE-11 SERVO

Gear trains with outputs ranging from 6 to 1,275 rpm are supplied with new 400-cps, 115- or 26-vac size-11 servomotors. **Backlash can be kept to 30 min.** The motor's stall torque is 0.63

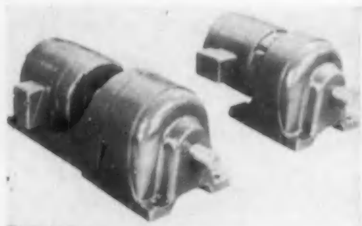
oz-in., and its no-load speed is 6,200 rpm.—G-M Laboratories, Inc., 4300 N. Knox Ave., Chicago 41, Ill.

Circle No. 29 on reply card

$\frac{3}{4}$-IN. SERVO MOTOR

A 400-cps servo motor the size of your thumb is now on the market for aircraft measurement and control systems. Priced at $160 list, the tiny two-phase machine has a no-load speed near 20,000 rpm, and a stalled torque of 0.11 oz-in.—General Electric Co., Schenectady, N. Y.

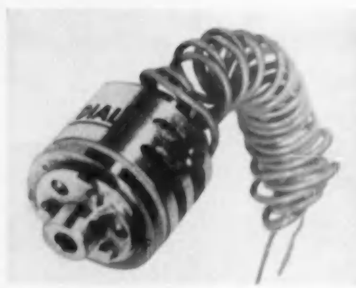
Circle No. 30 on reply card



GEARMOTOR LINE

A new line of gearmotors and gear reductors has been announced. The gearmotors will handle up to 30 hp, the reductors to 60 hp. Ratios for the gearmotors run from 6.2:1 through 292:1. The reductors are sold with attached motors using a common base. There is a 28-page booklet available with full specifications and load ratings for the line.—Link-Belt Co., Dept PR, 307 N. Michigan Ave., Chicago 1, Ill.

Circle No. 31 on reply card



TENSION CONTROL

Adding a slip attachment to a standard miniature electromagnetic clutch results in a device for controlling the tension of wire, thread, film, etc. It can exert from 0 to 50 oz-in.—Dial Products Co., 9 Ave. E., Bayonne, N. J.

Circle No. 32 on reply card

NEW PRODUCTS

SERVO MOTOR

Little over 1 1/8 in. in diam, a new high temperature servo motor claims a minimum life of 1,000 hrs at 150 deg C. Here are some of its characteristics:

- ▶ 115 volts 400 cps power
- ▶ stalled power drain 3.5 watts/phase
- ▶ stall torque 0.4 oz-in.
- ▶ no-load speed 7,200 rpm
- ▶ weight 3 oz

Servomechanisms, Inc., 625 Main St., Westbury, L. I., N. Y.

Circle No. 33 on reply card

SMALLER MOTORS

A new line of frame sizes in the 1/20 to 3/4 hp range is said to be substantially smaller and lighter than older models. –Century Electric Co., 1806 Pine St., St. Louis 1, Mo.

Circle No. 34 on reply card

TIMERS & RELAYS

SEVEN-DAY TIMER

A new time switch has seven **independent daily programs,** each with from 1 to 6 contact closures. Spring-wound motors are available in place of the conventional synchronous drive.–General Controls Co., Skokie, Ill.

Circle No. 35 on reply card

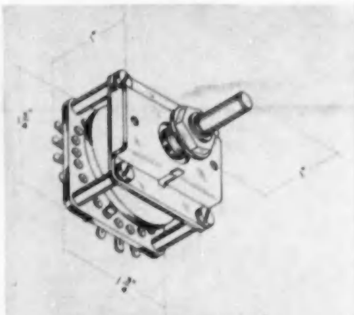
LOW-DRAIN TIMER

Originally developed for balloon instrumentation, a new, light-weight motor and cam switch-type timer **operates on 6 vdc with an 8-ma drain,**

NEW PRODUCTS

and at speeds accurate to within 1 per cent despite a voltage variation of 50 per cent. Contact arrangements are 4 spdt.—Brailsford & Co., Inc., 670 Milton Rd., Rye, N. Y.

Circle No. 36 on reply card



32-POSITION SWITCHES

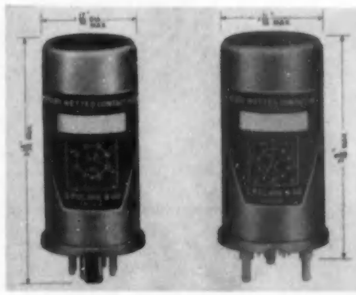
A new line of low-cost rotary switches measures 1¾ in. sq and **has from 2 to 32 positions per deck.** Additional decks add ⅜ in. to the length. Contacts are rated at 5 amps, 125 vac. Switch plates are made of Silicone-Fiberglas.—Shallcross Mfg. Co., Collingdale, Pa.

Circle No. 37 on reply card

SENSITIVE RELAY

Sensitivity to 80 microwatts in the face of 10 g vibrations is selling point of a new sealed relay. It's 2¾ in. tall. —The Liquidometer Corp., 36th St., & Skillman Ave., Long Island City, N. Y.

Circle No. 38 on reply card



MERCURY-WETTED RELAYS

A new series of multi-element relays switches up to a quarter of a kilowatt. They operate in 5 millisec with 2 watts coil input. Maximum rate of operation is 60 cps. **Life of over a billion operations is claimed,** with contact arrangements up to 4pdt.—C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Ill.

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(100) RELAYS. Stromberg-Carlson Div. of General Dynamic Corp. Industrial Bulletin, 22 pp. Describes six basic types for electromechanical switching, and some variations. Among the variations: fast and slow acting, slow operate, slow release, snap-action switch attachments, and plug-in.

(101) TANDEM TRANSISTOR. Marvelco Electronics Div. of National Aircraft Corp. Bulletin, 4 pp. Marvelco has housed two dc-coupled transistor elements in a single cage. Result: a simple two-stage cascade with current gain to 75 db.

(102) THE DIPOT. Servonics, Inc. Publication a-56-A, folded card. The Dipot, a multiturn precision potentiometer, operates according to Kelvin-Varley principles. Four models: linear, five-turn, linear ten-turn, and two servo types.

(103) PROCESS CONTROL. AEG, Germany. Bulletin (6x8½), 8 pp. Describes indicating, measuring, and recording instruments, and regulators, temperature-sensitive elements, gages, gas analyzers, and control panels.

(104) CLUTCHES & BRAKES. Electronic Mechanism, Inc. Bulletin, 4 pp. Covers a light-weight powdered-iron clutch that transmits 75 oz-in. of torque at 100:1 power gain, and a magnetic-iron-particle brake. The brake can't be used as a clutch.

(105) DATA PROCESSING FILMS. American Management Association. Bulletin 1355, 4 pp. Covers four films directed at and available to management: data processing and the computer, the computer system, the feasibility study, and the "electronic frontier".

(106) RECORDING & CONTROLLING. The Bristol Co. Bulletin P1245A, 64 pp. This big, two-color work on Dynamaster potentiometer and bridge instruments give specs on 3- and 12-in. strip-chart and 12-in. round-chart recorders, single and multiple variable recorders, and a high-speed recorder. Components treated, too.

(107) TERMINALS. Electrical Industries Div. of Amperex Electronic Corp. Stapled booklet, 112 pp. A veritable mountain of data on terminals, seals, headers, connectors, and closures. Section on general information describes manufacture, conductor material, design factors.

(108) INDUSTRIAL SIGNALS. Federal Sign & Signal Corp. Bulletin 100, 8 pp. Treats uniquely the three factors to be considered in selecting a signal, and suggests signals for 30 plant areas. Some attention to physics of sound and to signaling practices.

(109) CONTROL VALVES. Copes-Vulcan Div. of Blaw-Knox Co. Bulletin 1027, 4 pp. Discusses two air-operated units, one diaphragm-actuated, the other piston-actuated, for regulating pressure, temperature, or liquid level. Standard ranges: 3-15, 6-30, and 3-27 psig.

(110) PROCESS INSTRUMENTS. Barnes Engineering Co. Bulletin 5M 11-55, 8 pp. Contains condensed data on Barnes' infrared radiometers, infrared detectors, process refractometers, and infrared systems and components, and directs the reader to more detailed information about each.

(111) RHEOSTATS & RESISTORS. Rex Rheostat Co. Bulletin, 6 pp. Single and double-tube rheostats and resistors listed according to size, type, and ohmic values. Gradual- and graded-taper wound rheostats, winding machines also covered.

(112) MATHEMATICAL CHARTS. Frederick Post Co. News release, 2 pp. Tells about two calculating aids devel-

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oped by Sun Oil Co. They are card-stock charts, 8½x11, carrying log scales superimposed on log log grids.

(113) CHLORINE-GAS FEEDER. Builders-Providence Div. of B-I-F Industries, Inc. Bulletin 840-J8A, 4 pp. Presents data on a control-valve-regulated device adaptable to variations of automatic operation ranging from semi-automatic to automatic proportional.

(114) CONTROLLED - VOLUME PUMPING. Milton Roy Co. Technical paper 65, 8 pp. This is the talk Milton Roy's President Robert T. Sheen gave before the ISA last September. In it, ISA President Sheen tells why controlled volume pumps can be used as flow control instruments.

(115) GROWN DIFFUSED TRANSISTORS. Texas Instruments, Inc. Bulletins DLS 619-20-21, one sheet each. Describes one germanium and two silicon units that amplify electric signals to over 100 mc. and will oscillate to over 250 mc.

(116) TENSION CONTROL. Web Controls Corp. Bulletin, 4 pp. Says instant response to different pressures between driving and driven parts of a clutch or brake equips this unit for practically any type of winding or unwinding machinery.

(117) AUTOMATIC EDGEGUIDE. Web Controls Corp. Bulletin, 4 pp. Describes device using low-pressure air-sensing nozzles to control alignment. Total accuracy is plus or minus 0.012 in. on webs that "wander" ⅛ in. for every 100 ft of web length of 750 ft/min.

(118) PRINTED CIRCUITRY. International Resistance Co. Form S-088a, one sheet. Discusses a new laminate for printed circuitry (fluro-carbon plastic clad in copper). Features: low cold flow, zero water absorption, good machineability, impervious to acids, alkalies, organic solvents.

(119) WIRE-WOUND CONTROL. International Resistance Co. Form SO24, 4 pp. Covers a little device that can meet potentiometer and rheostat applications within its 2-watt power rating. Resistance values range from 1 to 15,000 ohms.

(120) CYLINDERS & VALVES. Pathon Mfg. Co. Bulletin 22A, 36 pp. Charts and engineering drawings describe 16 cylinders, eight for 2,000-psi operation, and eight for 1,000 psi, designed primarily for oil, but adaptable to treated water. Nine control valves also considered.

(121) NEW PERIODICAL. Georator Corp. "Nobrush Notations," one sheet. Covers doings in the field of brushless, permanent-magnet generators and frequency converters. The one at hand (Vol. 1, No. 2) treats 60-420 cycle frequency converter with synchronous motor drive.

(122) APPLIED MATHEMATICS. Industrial Mathematics Society. Booklet (6x9), 16 pp. In "Industrial Mathematics in an Industrial Economy", IMS tells about itself and its aims, and lists requirements for membership. An application blank is included.

(123) SOLENOID VALVES. Atkomatic Valve Co. Catalog 200. Contains specs, dimensions, pressures, and applications for Atkomatic's line of electric two-way solenoid valves for air, gas, steam, and liquid flow control.

(124) DC POWER SUPPLIES. Kepco Laboratories. Bulletin B 356, 4 pp. Presents specs for more than 40 voltage-regulated units powered by 105-150 volts, 60 cycles. Recovery time is less than 50 microsec, and output impedance is less than 0.01 ohms from 20 cycles to 100 kc.

(125 ELECTRONIC AUTOCOLLIMATOR. Optronics. Bulletin, one sheet. Data on an instrument that optically measures minute changes in angles (as small as 0.03 sec of arc, the angle subtended by about 1 ft in 1,000 miles) and converts the changes into a dc voltage.

(126) WINDING MACHINES. Geo. Stevens Mfg. Co., Inc. Catalog 56, 69 pp. (including price list). A useful page of winding formulas brings up the rear of this weighty presentation. Practically every Stevens coil winder, and a lot of accessory equipment, are described.

(127) ELECTRONIC TUBES. Chatham Electronics. Bulletin, 4 pp. Includes information about rectifiers, twin-power triodes, voltage regulators and reference tubes, thyratrons, hydrogen thyratrons, clipper diodes, and special-purpose tubes.

(128) SWITCHES & ACTUATORS. Electro-Snap Switch & Mfg. Co. Catalog 12, 24 pp. Given four pages of basic switches, four of actuators, four of industrial switches, and five of aircraft switches, and the result is a lot of information.

(129) ROTATING COMPONENTS. Norden-Ketay Corp. Bulletin 376, 4 pp. Prepared for the engineer, this offering gives characteristics of more than 138 synchros, servomotors, resolvers, induction motors, and tachometer generators.

(130) VOLT-OHM MILLIAMMETER. Phaostron Instrument & Electronic Co. Catalog sheet. Describes the "666" which uses only two jacks in measuring voltage, current, decibels, resistance.

(131) DECIMAL DIGITIZERS. Coleman Engineering Co. Bulletin CR-185, 4 pp. Illustrates and describes commutator, digitalizing unit, and other components for translating shaft position into straight parallel binary or binary-coded digital output.

(132) INSULATED METAL FOIL. American Machine & Foundry Co. Bulletin FRF-10-6 (4x7½), 4 pp. Offers samples of five Teflon-coated foils used in subminiature capacitors, coil forms, transformers, shielding, and flexible packaging.

(133) SOLENOID VALVES. Automatic Valve Co. Forms 111, 113, one sheet each. Contains information on three four-

way, four-port valves: a single-solenoid with ¼-in. pipe, and two double-solenoids, one with ¼-in. pipe and the other with ⅜-in. pipe. All pilot-operated, all with pressures of 25-150 psig.

(134) CONTROL GEAR. Muirhead & Co., Ltd. (England). Bulletin 7730-B, one sheet. Describes an hydraulic relay and gyroscopic unit, which together form a device for ship stabilization. Three controls determine dither and adjust the relay's oil pressure (40-115 psi).

(135) AMPLIFIERS & ACCESSORIES. Weston Electrical Instrument Corp. Form 2-14, 20 pp. These "notes" cover two dc amplifiers, fluxmeter, control unit, sensitizing amplifier, product resolving system, and photocell range network.

(136) X-Y PLOTTER-RECORDER. Librascope, Inc. Bulletin, 8 pp. Presents data on two basic models, one for resistance inputs, the other for dc signal inputs. Static accuracy is 0.1 per cent, dynamic accuracy 0.5 at 5 in./sec.

(137) COMPUTER COMPONENTS. Librascope, Inc. Bulletin, 4 pp. Illustrates ten electrical and mechanical components for computers, gives outline specs.

(138) ROLLER BEARINGS. Link-Belt Co. Book 2658, 8 pp. Dimensions of self-aligning bearings and procedure for their selection take forefront here, with applications and load ratings a close second. Selection formulas shown in use.

(139) POWER SUPPLIES. NJE Corp. Technical data file. Specs on more than 500 stock models deal with high voltage, low current; zero-lag low voltage, high current, and standard- and laboratory-grade plate supplies. Methods of rating performance also covered.

(140) MANOMETERS. The Meriam Instrument Co. Bulletin G-10, 4 pp. Gages for pressure, liquid levels, and vacuums and flows are grouped according to four designs: U-tubes, straight U-tubes, well-types, and inclined tubes. Working pressures range from 15 to 2,000 psi.

(141) SURFACE MEASUREMENT. Micrometrical Mfg. Co. Form LT18. This extension of an American Standards Association "standard" defines terms, gives characteristics of roughness, waviness, and lay, explains root-mean-square and arithmetical averages. Profilometer recordings shown.

(142) TANK MIXING EDUCTOR. Schutte & Koerting Co. Bulletin Supplement 2M, one sheet. Describes a submerged-type liquid jet eductor cast in one bronze or iron piece.

(143) SELECTOR VALVES. Aircraft Products Co. Data sheet. Tells about three-way, solenoid-type units that offer flow in any direction, operate up to 3,000 psi, and are said to handle 85 per cent higher flows than conventional models.

(144) WATER AND WASTE TREATMENT. Milton Roy Co. Technical paper 64, 6 pp. Discusses typical systems that use controlled-volume pumps to meter water treatment chemicals and slurries, and illustrates best uses for them.

(145) DELAY LINE PACKAGES. Computer Control Co. Technical Marketing Associates, Inc., release, 2 pp. Covers two unit delays (packages of 15 and 30 1-microsec delay lines) for video memory and storage. Intervals accurate to 2 per cent.

NEW PRODUCTS

LONG-LIFE SNAPPER

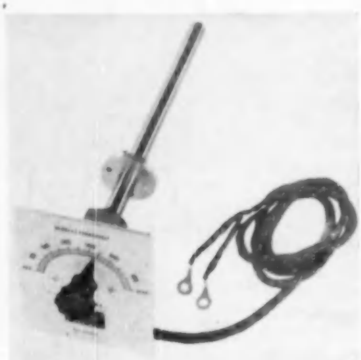
Here are the claims for a new snap-action switch:

- ▶ 10 million cycles life
- ▶ 10-amp contacts at 115 vdc
- ▶ 350 to minus 100 deg F

The BM-12,000 is described as subminiature in size.—Acro Mfg. Co., Columbus 16, Ohio.

Circle No. 40 on reply card

DETECTORS



HI-TEMP THERMOSTAT

A new adjustable high-temperature, snap-action-type thermostat is sold in two ranges: **from 600 to 1,900 deg F** and from 600 to 2,400 deg F. Accuracy of within ¼ of 1 per cent of full range is claimed. Its sensing tube is 10½ in. long.—Franklin Dales Co., 180 E. Mill St., Akron, Ohio.

Circle No. 41 on reply card

SPEED-CONTROL SWITCH

The maker of little snap-action centrifugal-force-operated switches claims an operating accuracy of ¼ of 1 per cent. They are used as motor operation detectors (i.e., to indicate the operation of important blowers), or as governors. Size is 1⅛ in. in diam.—Torq Engineering Products, Inc., Interstate St., Bedford, Ohio

Circle No. 42 on reply card

LOW-COST TEMP CONTROL

A little snap-action temperature-operated switch is offered as a thermostatic control for original equipment manufacturers. Temperature settings range from minus **10 to 350 deg F.** Contact rating is 25 amps at 120 vac. —Spencer Thermostat Div. of Metals & Controls Corp., Attleboro, Mass.

Circle No. 43 on reply card

FRONTIER

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Science has unlocked a vast new frontier—the limitless areas of space, man's most daring and intriguing exploration yet. Leading in the race to conquer these new worlds are American scientists and engineers . . . descendants of the "not-so-long-ago" pioneers who developed our great country.

The scientists and engineers at Remington Rand Univac are leading the field and are part of the team that is setting "*new* standards for others to follow."

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At South Norwalk we have immediate openings for Mechanical and Electro-Mechanical Engineers with a bachelor's degree in *Engineering*. Extensive mechanical design background may substitute for some college. Men selected will do basic preliminary design and layout of small mechanisms. Work will require the development of original ideas and the ability to apply logical analysis to design problems.

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NEW PRODUCTS

PRESSURE TRANSDUCER

A thumb-sized flush diaphragm pressure transducer uses a bridge circuit for a 80 mv max output. The stainless-steel device is offered in ranges from 0 to 15 to 0 to 5,000 psi absolute. Natural frequency is 5,000 cps. –North American Instruments, Inc., 2420 North Lake Ave., Altadena, Calif.

Circle No. 44 on reply card

TACH GENERATOR

115 volts 60 cps excitation is said to suit a tachometer generator for industrial servos. It can be mounted on the rear of the maker's 1-, 5-, or 10-watt servo motors. Output is 6 volts per 1,000 rpm.–Diehl Mfg. Co., Finderne Plant, Somerville, N. J.

Circle No. 45 on reply card

PRESSURE POT

A new pressure transducer, using resistance elements of from 2 k to 50 k ohm, is said to be its maker's first excursion into the pressure transducer field. Output is proportional to altitudes from 1,000 to 20,000 ft with the use of both absolute and differential pressure elements. Each element's pot has dual functions as well. Air speed readings of from 205 to 590 knots are also within the instrument's range.–Components Div. of Fairchild Controls Corp., 225 Park Ave., Hicksville, N. Y.

Circle No. 46 on reply card

THERMISTOR KIT

Three new thermistor kits priced from $9.95 to $39.95 are offered with instructions on their use in temperature-correcting networks, etc.–Thermistor Corp. of America, Metuchen, N. J.

Circle No. 47 on reply card

NUMBERS MACHINES

PULSE BURST MAKER

New pulse-burst and single-pulse generators produce microsecond-wide pulses of any number after a triggering input pulse. Power source is standard 115 vac, and output 18 or 35 volts into 25 and 100 ohms, respec-

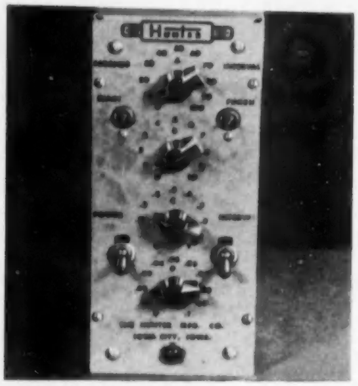
tively. See last month's first new product for a more complete story on these items.—The Jacobs Instrument Co., Bethesda 14, Md.

Circle No. 48 on reply card

PULSE GENERATORS

Two new pulse generators offer outputs ranging from millimicrosecs up, **with repetition rates up to 100 kc.** Pulse widths range from 0.05 microsec to 100 microsec.—Allen B. Du Mont Laboratories, Inc., 750 Bloomfield Ave., Clifton, N. J.

Circle No. 49 on reply card



INTERVAL TIMER

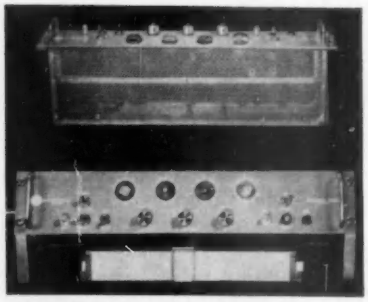
Intervals from 0.01 to 111 sec in 0.01 steps are possible with a new instrument which, says the maker, uses RC circuits for basic timing but avoids errors due to voltage variations and drift through unique circuitry.—Hunter Mfg. Co., 930 S. Linn St., Iowa City, Iowa.

Circle No. 50 on reply card

NAVIGATION COUNTER:

A numerical navigation readout provides the words "left" and "right" in addition to numerical indication. The words pop up whenever the count goes through the zero point.—Durant Mfg. Co., 1929 N. Buffum St., Milwaukee 1, Wis.

Circle No. 51 on reply card



FREQUENCY COUNTER

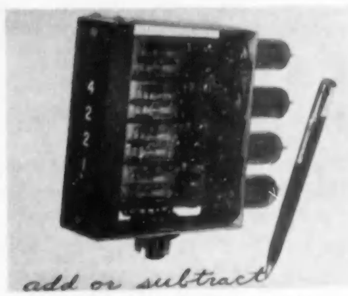
Counting intervals range from 0.1 to 1 sec in a new glow-tube frequency indicator, which will operate with **inputs up to 60 kc.** Inputs may range from 25 mv to 120 volts.—Hupp Instrumentation, 2119 Sepulveda Blvd., Los Angeles 25, Calif.

Circle No. 52 on reply card

DELAY LINE:

Tapped every two microsecs, a new delay line offers a total delay of 200 μ sec with an impedance of 400 ohms and a rise time of 4μ sec.—Components Div. of Litton Industries, 215 S. Fulton Ave., Mt. Vernon, N. Y.

Circle No. 53 on reply card



ADD-SUBTRACT COUNTER

An externally applied 115-or 250-volt input will make this small counter count "up or down". Readout is either in binary coded decimal or in a staircase voltage. Long-life neon bulbs are used in a unique counting circuit, says the maker. It will handle **up to 50 kc inputs** driven by 90-volt negative pulses, and its output is capable of driving a similar plug-in package. —Controller Instrument Co., 1612 Que St. N. W., Washington 9, D. C.

Circle No. 54 on reply card

MULTIPLEXERS

From 43 to 88 low-signal-level transducers are sampled and their **output voltages converted into pulse widths**

for tape recording by a new multi-coder, 4½-in. in diam by 13 in. long. Sampling rates of 2.5, 10, or 20 rps are available for inputs from 15 to 30 mv.—Applied Science Corp., P. O. Box 44, Princeton, N. J.

Circle No. 55 on reply card

QUAD-PULSE GENERATOR
The Model 340 quadruple pulse generator produces square pulses having a 1 millimicrosec rise time and **widths varying from 0.001 to 0.1 microsec** (panel-selected) in each of four channels. Each pulse can be independently varied in 1 db steps over the range of 0.006 to 100 volts into the low-impedance cables. Output can be matched with any impedance from 50 to 200 ohms.—Electrical & Physical Instrument Corp., Long Island City 1, N. Y.

Circle No. 56 on reply card

ELECTRONIC COUNTER:
Little larger than a desk dictionary, a new 2,000-cps counter indicates to four digits by glow tubes. As an interval timer, it works with a motor and photocell circuit to measure in intervals of 1/10, 1/100 or 1/1,000 sec. —Hunter Mfg. Co., 930 S. Linn St., Iowa City, Iowa.

Circle No. 57 on reply card

POWER SOURCES

300-VOLT POWER SUPPLY
Housed in an attractive metal case, a new regulated power supply delivers **300 vdc at 20 to 200 ma, regulated to within 0.04 per cent.** It also provides a 6.3-vdc filament source filtered to 25 mv ripple, running up to 5 amps. —Link Aviation, Inc., Binghamton, N. Y.

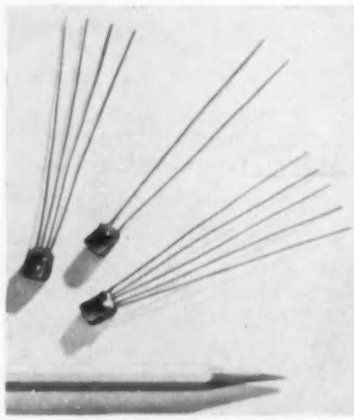
Circle No. 58 on reply card

NEW PRODUCTS

PORTABLE AC

A lunch-box-sized case with shoulder strap provides 115 vac for **50 min at 50 watts,** or 35 min at 75 watts. It weighs 9½ lb and has a built-in charger. The batteries are said to require no attention, but a battery condition indicator is available if you must look after them.—Dynaseal Lighting Corp., 5 Hadley St., Cambridge 40, Mass.

Circle No. 59 on reply card



SUB-MINIATURE SELENIUMS

Though the objects shown here may look like transistors or germanium diodes, they are actually miniature selenium rectifiers capable of carrying **up to 25 ma and 148 volts.** Full- and half-wave models are available.—Bradley Laboratories, New Haven, Conn.

Circle No. 60 on reply card

TEST & RECORDING

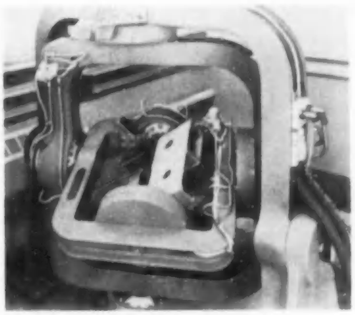
TEMP SWITCH TEST SET

A new temperature switch test set operates in a range of from 200 to 1,000 deg F to indicate operating differential and calibration.—Ram Meter, Inc., 1100 Hilton Rd., Detroit 20, Mich.

Circle No. 61 on reply card

8-CHANNEL OSCILLOGRAPH
Designed primarily for handling analog computer outputs, a new eight-channel oscillograph uses dc input amplifiers to produce 0.1 volt per cm sensitivity. Input impedance is 5 megohms and response is flat to 20 cps, down 2 db at 50 cps for all amplitudes to 4 cm peak to peak. Nine chart speeds range from 0.25 mm per sec to 100 mm per sec, with true rectangular coordinate recording.—Industrial Div. of Sanborn Co., 195 Massachusetts Ave., Cambridge 39, Mass.

Circle No. **62** on reply card



FLIGHT TABLE
Hydraulic servos convert voltages to positions in a new flight simulator table with 3 deg of freedom. It will accommodate equipment 17 by 13 in. Its basic specifications:
- ▶ 40,000-deg/sec² roll acceleration
- ▶ 250-deg/sec max roll velocity
- ▶ 240-deg max displacement
- ▶ 20,000-deg/sec² max pitch acceleration
- ▶ 150-deg/sec max pitch velocity
- ▶ 90-deg max pitch displacement
- ▶ 8,000-deg/sec² max yaw acceleration
- ▶ 125-deg/sec max yaw velocity
- ▶ 180-deg max yaw displacement
- ▶ servo accuracy within 0.5 deg.

It's intended for operation from analog computer output.—Color Television, Inc., 920 E. San Carlos Ave., San Carlos, Calif.

Circle No. **63** on reply card

ABSTRACTS

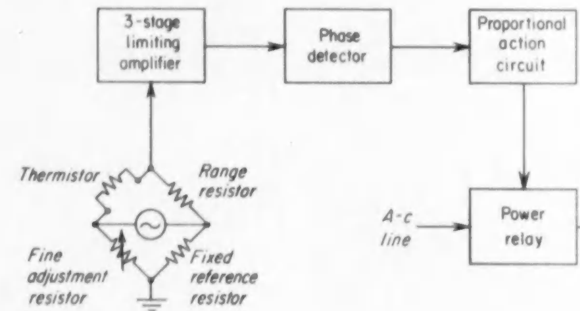
Temperature Control

From "Thermistor Temperature Control" by P. R. Malmberg and C. G. Matland, Westinghouse Research Labs., "Review of Scientific Instruments", March 1956.

Developed specifically for the precise control of pressure and temperature in the vapor phase of a mercury-liquid system, the temperature controller described by the authors should find a host of other applications in industry and research. In the application for which it was designed, this controller maintained temperature at 200 deg C within plus or minus 0.03 deg C over a four-hour period, and within plus or minus 0.1 deg C during an eight-day period.

The block diagram (Figure 1) describes the major stages of the thermistor temperature controller. Here a thermistor (types 51A2 or 32A12) serves as one arm of an ac-excited bridge, with the temperature control-point set by a range resistor. Since the thermistor changes resistance with temperature, any variation in temperature will result in an unbalanced voltage at the bridge. This output voltage is then amplified, rectified, and filtered—thus converting into a smooth dc signal.

FIG. 1

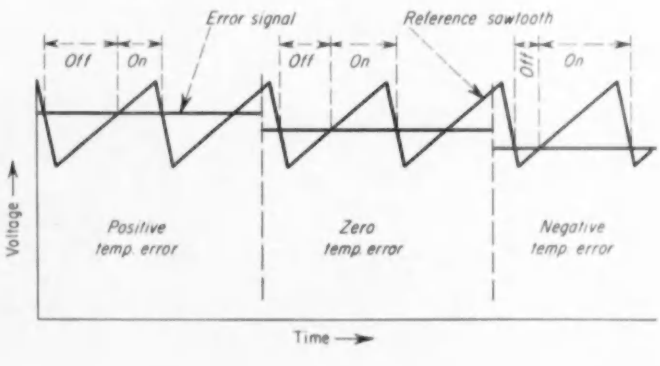


At this point the controller could be used to turn on a heater for a time necessary for the controlled process to return to essentially zero temperature error. However, processes being what they are, a considerable overshoot in temperature could occur, minimizing the close control desired by the operators.

Thus the authors added a proportional-action circuit that applies a fractional portion of the available heating power in direct proportion to temperature error magnitude. Thus, as the error approaches the preset point the added heat diminishes to zero, or full "off". "The range of proportional action, i.e., the temperature excursion needed for a change from 0 to 100 per cent fractional 'on' time of the controlled power, is adjustable from 3 deg C to less than 0.01 deg C by means of a gain control."

Figure 2 shows the operation of the proportional-action stage of the temperature controller. A reference sawtooth is generated and compared, by a sensitive relay, with the error signal, thus turning the power "on" and "off" in a regularly repeating cycle of a

FIG. 2



fixed period. Here, the fractional "on" time of the controlled power determines the average heating power, and through the use of the sawtooth reference, depends linearly on the temperature error.

Thus the fractional "on" time is initially adjusted to maintain sufficient heat input into the process to overcome heat losses and retain the temperature at the desired level. This is shown in the middle zone of Figure 2. But if the error is positive, the "on" time is reduced accordingly—as shown in the left zone. And similarly, a negative temperature error increases the "on" time, increases the heat input, and restores the temperature to the set-point.

The article contains the complete electronic schematic diagram of the thermistor temperature controller, discusses a simple method for controlling only a fraction of the total heater input by using two variable transformers, and reviews the basics of thermistor-bridge design and thermistor calibration for this circuit.

Dutch Distillation

From "Response of Concentrations in a Distillation Column to Disturbances in the Feed Composition" by Dr. H. Voetter, Royal Dutch Shell Lab., Amsterdam. Presented at the Society of Instrument Technology Conference on Plant and Process Dynamic Characteristics, Cambridge, England, April 4-6, 1956. Abstract prepared from notes by John Tunstall, McGraw-Hill, London.

The second part of Dr. Voetter's talk was considered a major contribution to the control of distillation columns. Under investigation were several possible control systems using a heavily instrumented pilot column. With the column under manual control, sinusoidal disturbances were imposed, in turn, on

- steam flow to the reboiler
- water flow to the condenser
- reflux flow

Using a twelve-channel process analyzer, the resulting pressures, temperatures, distributions, fluid composition, vapor flow, and levels were simultaneously recorded.

The response speed of automatic control of temperature and pressure, when one of these was controlled manually, was examined and compared with three systems in which both variables operated under automatic control. In these systems.

1) temperature was controlled by steam flow to the reboiler, pressure by the cooling water;

2) temperature was controlled by the reflux, pressure by the reboiler steam flow;
3) temperature was controlled by the reflux, pressure by cooling water.

The frequency response of temperature, both with and without pressure control, indicated these major findings:

1) Introduction of pressure control on temperature control slows down control in the first system, but has little effect on the two other systems.

2) Temperature control might increase the speed of the pressure control system.

The equipment used in making these tests evoked considerable interest on the part of the men attending the conference. Up to twelve process variables can be recorded simultaneously on the analyzer, using photogalvanometers arranged in four banks. Appropriate transducers convert the process variables to be measured into compatible signals for recording. The sine wave generator that delivers a 0-3 psi continuous pneumatic output contains an adding relay for open- and closed loop operation and a variable-speed mechanism. It is mounted in an evacuated box and weighs 77 lb.

One transducer of particular interest measures the liquid concentration. It consists of a tubular capacitor through which the liquid is continuously sampled. The capacitor forms part of an oscillator, the frequency of which gives a measure of the liquid dielectric constant. A frequency converts the oscillator output into a dc signal. Temperature variations which affect the liquid dielectric are reduced by cooling the capacitor.

Miniature Components

From "Components for Transistor Circuits" by the staff of "Electrical Manufacturing", March 1956.

Since the advent of small-size transistors, much work has gone into the development of diminutive components for use in transistor circuits. Herewith the staff of *Electrical Manufacturing* reports on the current state of such components developed under the cognizance of the Signal Corps Fngineering Labs.

This seven-page survey details, with text and illustrations, a representative selection of the components and their design factors. The report will no doubt be of interest to instru-

mentation and control designers who develop or package transistor-operated devices.

The article includes discussion of sockets, resistors, capacitors, inductors and transformers, rectifiers, switches, connectors, quartz crystals, and printed circuits.

On Manpower Shortage

From "Encouraging More Technologists", "Journal of the British Institution of Radio Engineers", March 1956, page 113.

The germ for this British IRE editorial was what is known in England as a "command paper" or government publication of special significance. This one dealt with technical education. Even by itself, the original paper probably would make good reading for Americans, since the problems it talks about are concerning the U. S. government, too. But in the pages of this journal, the pronouncement takes on even more interest, for here it is placed side by side with comments of some of those Britons who are being asked to ease the "technologist" pinch.

According to the paper, the number of British university students now taking science and technology courses (29,013) has increased 124 per cent over the number enrolled in like courses in 1938-39. This new peak represents 34.5 per cent of the university population, or 4,200 degrees in straight science and 1,800 in technology a year. (In England the term "technologist" is more embracing than "engineer".) The journal deems these figures praiseworthy, but with reservations, the same kind of reservations that have been advanced in this country: the status of the engineer still is not where it should be, all parents have not as yet been sold on higher education, and a larger building program remains to be approved and started.

Allowing private industry to set down employees' tuition fees for "sandwich courses" as business expenses is a good idea as far as it goes, the journal says in referring to a proposal embodied in the paper. But, it adds, public departments employing technologists should be encouraged to do their part, too. One thing public agencies can do, it says, is supply candidates for part-time teaching in specialized subjects. The shortage of good educators is as acute in England as it is here. Although the government cannot solve the problem by

itself, it can do its part, the journal says. The technical societies can help, too.

A huge recruiting drive for specialists is already under way in England, Scotland, and Wales.

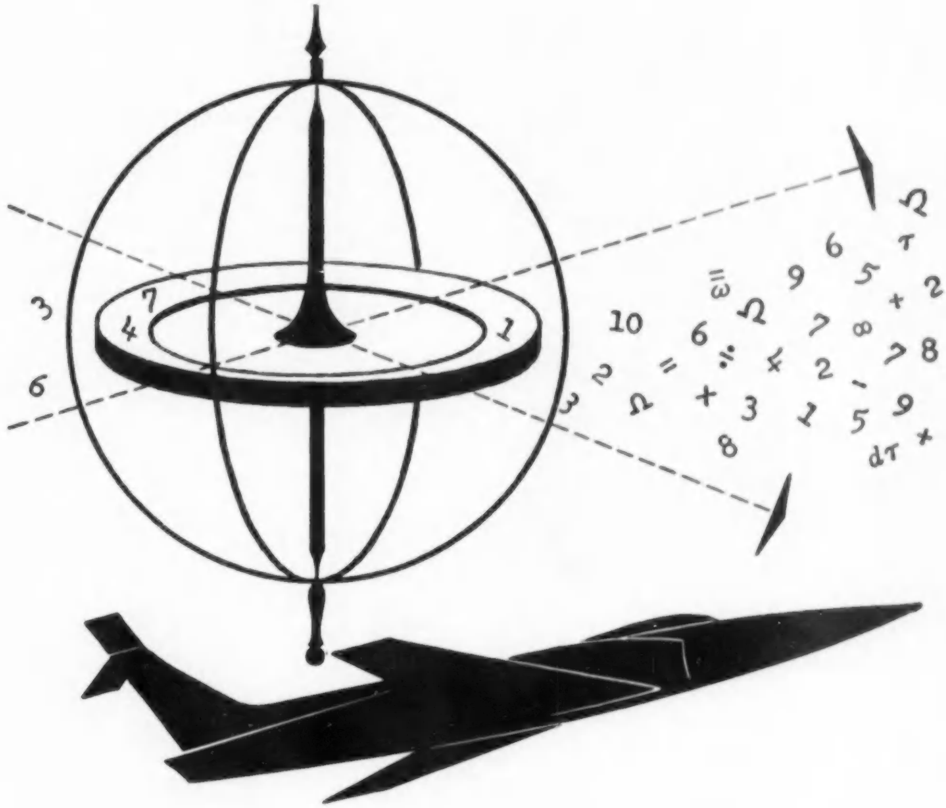
Briefly Noted . . .

The Office of Technical Services, U. S. Dept. of Commerce, frequently publishes literature germane to instrumentation and control. Herewith is a list of such publications recently made available. Publications may be obtained from: Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., at the price listed at the end of each description. Ed.

Increasing the Reliability of Electronic Equipment by the Use of Redundant Circuits by C. J. Creveling, Naval Research Lab. Says that the use of redundant circuitry in complex electronic equipment may increase reliability, but circuits must be designed so that failure of some parts will not cause failure of others. Equations relating reliability to the number of circuit elements in the redundant and nonredundant cases are derived and applied to examples. (Order PB 111740, 50 cents.)

A Survey of Domestic Electronic Digital Computing Systems by Martin H. Weik, Ballistic Research Labs., Aberdeen Proving Ground, Maryland. This report, based on a questionnaire submitted to manufacturers and users of digital computers, surveys 84 systems. It discusses the basics of each system for the benefit of persons new in this field, and then details their design, applications, and characteristics—including operations and reliability (Order PB 111996, $4.75.)

A Positive Displacement Pump for Accurate Metering of Liquids by L. R. Crisp and F. O. Anderson, National Institutes of Health. This new-type positive-displacement pump accurately meters liquids to obtain constant flows, automatic proportioning, and pilot studies of automatic water-chemical treatment. The report describes in detail the pump's construction, uses, and limitations. Basically, the pump consists of two syringes operated in a reciprocal manner. Each syringe has a fixed stroke of 1 in. with the capacity a direct ratio to the input speed as obtained from a variety of synchronous motors and variable speed drives. (Order PB 111851, 50 cents.)



NEW BOOKS

Control of Nuclear Processes

PROCEEDINGS OF THE 1956 MID-WINTER CONFERENCE ON INSTRUMENTATION AND CONTROL OF INDUSTRIAL NUCLEAR PROCESSES, *sponsored by the New York Section ISA, Feb. 9, 1956. Available from the Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa. $2 to ISA members, $3 to nonmembers.*

In February the New York Section of the Instrument Society of America sponsored a highly successful and forward-looking conference. Eight capable speakers presented material on instrumentation and control of industrial nuclear processes. Through the commendable auspices of the national office, the ISA gathered these talks into a paper-bound, mimeographed book.

The book, of course, reflects the planning of the conference committee, for it covers many aspects of nuclear process control—possibly one of the few books available with this breadth of coverage. The first paper details the basics of the control of nuclear reactors, and the others comprise chapters on reactor control, protection of personnel, and public health and safety. All augur well for the future of industrial atomics.

Here is a list of the papers, their authors, and brief reviews of each:

► *Fundamentals for the Control of Atomic Reactors*, J. M. Stein, Combustion Engineering, Inc. Describes the basic physical phenomena in the nuclear power field, discusses the ways in which these phenomena make reactors a physical possibility, describes the various kinds of reactors under consideration in the field today, and points out the peculiarities of reactors which must be taken into consideration for adequate instrumentation and control.

► *Reactor Control and Instrumentation*, Robert L. Detterman, Foster Wheeler Corp. Points out that in a reactor the available energy is equivalent to many millions of tons of coal, ready for instantaneous release if the reactor is not properly controlled. Fortunately, several means are available to the control engineer to effect safe control of the reactor while obtaining the desired power output. Among these are the neutron absorber that is moved in and out of the reactor core, the neutron reflector that surrounds the reactor to control leakage, the inherent negative temperature coefficient of reactivity, and the slow-

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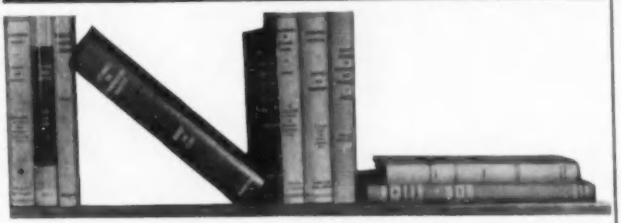

F R E E

Published 1955

Automatic Feedback Control System Synthesis

by John G. Truxal

Associate Professor of Electrical Engineering
Polytechnic Institute of Brooklyn

A notably complete and current compilation of methods useful in the design of feedback systems. This graduate-level account of modern feedback theory, with emphasis on the synthesis of feedback control systems, includes an abundance of worked examples and concise summaries which make it invaluable for both advanced students and practicing engineers.

"The book is highly recommended to all engineers."
—*Physics Today*, August, 1955

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☐ **Servomechanism Analysis** by G. J. Thaler, Associate Professor of Electrical Engineering, U. S. Naval Postgraduate School and R. G. Brown, Senior Project Engineer, A. C. Spark Plug Division, General Motors Corporation. Publisher's Edition, $8.00 Club Price, $6.95.

☐ **The Compleat Strategyst** by J. D. Williams, Mathematics Division, The Rand Corporation. Publisher's Edition, $4.75. Club Price, $4.10.

☐ **Electronics for Communication Engineers** by John Markus and Vin Zeluff, Associate Editors of *Electronics*. Publisher's Edition, $10.00. Club Price, $8.50.

☐ **Fundamentals of Electronic Motion** by W. W. Harman, Associate Professor of Electrical Engineering, Stanford University. Publisher's Edition, $7.00. Club Price, $5.95.

☐ **Engineering Electronics** by G. E. Happell and W. M. Hesselberth, Associate Professors of Electrical Engineering, Purdue University. Publisher's Edition, $8.00. Club Price, $6.95.

☐ **Industrial Electronic Control,** 2nd Ed., by W. D. Cockrell, Industrial Engineering Divisions, General Electric Company. Publisher's Edition, $6.00. Club Price, $5.00.

☐ **Handbook of Industrial Electronic Circuits** by John Markus and Vin Zeluff, Associate Editors of *Electronics*. Publisher's Edition, $7.50. Club Price, $6.45.

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NEW BOOKS

starting neutron groups. Proper reactor design and appropriate selection of the control variable thus aid the safe utilization of reactor power.

▶ *Instrumentation for the Radioactivity Laboratory*, Philip Shevick, Nuclear Instrument & Chemical Corp. Lists some uses of radioisotopes in industry, such as in wear studies of rubber tires and electrical contacts, research in metallurgy, detection of impurities, and the study of many chemical and diffusion processes. Discusses the question that must be answered in the use of radioisotopes, such as the radioisotope's decay time, radiological hazards, and counting of the ionized particles. Four new counting devices for use in nuclear scaling (glow-transfer neon tubes, ferromagnetic elements, transistors, and radiation analyzers for gamma ray spectroscopy) come in for extensive review.

▶ *Protective Nuclear Instrumentation for Public Health and Safety*, Nicholas Anton, Anton-Electronic Labs., Inc. Reviews the procedure and the equipment needed to protect the public from the potential hazards of a reactor facility. Recommends a complete survey of the proposed site prior to construction and covers required testing after the facility is operative.

▶ *Reactor Power Plants—Control and Operation*, Stephen Malaker, Daystrom, Inc. Compares a fissile power plant with a fossil-fuel power plant and points out the basic differences in controlling the outputs. Derives the dynamics of nuclear reactor operation, the result showing that the reactor's transfer function compares with that of an integrator with decreased gain at low frequencies. Emphasizes, with the use of a block diagram, that the reactor characteristics and the power plant parameters must be considered as an integrated control system.

▶ *Industrial Nuclear Instrumentation*, Ernest H. Wakefield, Radiation Counter Labs., Inc. Reviews the available instrumentation for the detection and counting of the important nuclear radiations of alpha and beta particles, gamma rays, and neutrons. This survey covers ion chambers, photographic film, conduction detectors, chemical integrating indicators, cloud chambers, proportional counters, Geiger-Mueller counters, and scintillation counters. Some of these are mentioned only briefly. Another important instrument mentioned in great detail is the gamma ray spectrometer.

▶ *Instrumentation for Personnel Pro-*

tection, F. P. Cowan, Brookhaven National Lab. This short paper details the permissible levels of atmospheric radiation contamination that assure safe working conditions. To determine safe levels several instruments are available to provide warning when excessive radiation occurs. Among these are the ionization chamber and the scintillation detector, the first for beta and gamma rays and the latter for fast neutrons. Other devices gather airborne radioactive contaminants, such as vacuum cleaners, filter papers, and sampling cans, and these feed into a detection device.

▶ *Instrumentation in the Industrial Atomic Future*, H. F. Davis, Minneapolis-Honeywell Regulator Co. Predicts that until 1960 the government will still be the biggest customer of nuclear instruments, purchasing about \$115 million, and that the industrial market will account for \$83 million. But since there are about 100 companies manufacturing instrumentation equipment and the profit levels are small, these figures lose some of their initial attractiveness. Lists instrumentation for nonreactor applications, and predicts some instruments that will probably be developed in the next ten years. In the list of new instruments appear: boron thermopile with greater sensitivity and speeds of response than present devices, automatic startup controllers comprising a 10-decade logarithmic measurement of reactor activity, colorimeters for liquid separations, polarographs for uranium-plutonium measurements, and liquid-liquid interface meters.

Written for Management

ELECTRONIC DATA PROCESSING FOR BUSINESS AND INDUSTRY. *Richard G. Canning, Partner, Canning, Sisson & Associates, 6 by 9 in., 332 pp. Published by John Wiley & Sons, Inc., New York City. \$7.00.*

This book grew out of the author's experience in teaching a university course on electronic data processing—mostly to business and industrial management people. He has combined the material he presented and his answers to the many questions asked by his "students" into a recommended course of action for management groups approaching the idea of electronic data processing for the first time. The approach is systems engineering, in this case the efficient use of data processing equipment within a company that must be viewed as an integrated operation.

The book starts with the concept of "Electronic Data Processing as a New Management Tool" that the executive can use to his company's ad-

NEW BOOKS

vantage. The author assumes that the executive willing to investigate the potential of data processing will read the book and prepare to establish (last chapter) "Management's Program for a Reliable System".

The intervening chapters cover these topics: patterns of data processing, summary of electronic data processing machines, programming of typical clerical operations, and the systems study, as well as the initial and detailed design of the electronic system, the role of operations research, and equipment characteristics.

Canning's book reads easily and should appeal to the large audience searching for additional information in the rapidly expanding field of electronic data processing. The author includes an additional lesson in management techniques in the appendix. This is a talk by Robert Tannenbaum entitled: "Overcoming Barriers to the Acceptance of New Ideas and Methods". It would seem that Canning would like to see converts to electronic data processing sufficiently prepared to circumvent objections to the installation of such systems that may be raised by either or both the board of directors and the clerical staff.

Higgins on Soviet Text . . .

GRUNDLAGEN DER SELBSTTATIGEN REGELUNG ELEKTRISICHER MASCHINEN *(Fundamentals of the Automatic Control of Electrical Machinery). M. W. Mejerov.* 172 *pp. Published by VEB Verlag Technik, Berlin, Germany.* 18 *D.M.*

This excellent book considers the speed control of dc motors and the voltage control of dc generators.

Assuming a knowledge by the reader of basic dc machine theory, the author derives the fundamental equations of performance, transforms them, and obtains therewith the transfer functions of various types of dc machines. Next he determines the nature of stability through use of the Hurwitz, Nyquist, Michailov, and Neimark stability criteria, and this leads naturally to detailed investigation of various feedback means of stabilizing a system and compensating it.

The quality of system performance is based on the transient response determined from the frequency-transfer functions (in accordance with the theory set out in Solodonikoff's book, reviewed in CONTROL ENGINEERING, December 1954, page 51), and subsequent analysis.

Each major phase of theory is illus-

trated by detailed solution of one or more specific examples, typifying systems and calculations as they occur in practice. Tabulation of numerous equivalent circuits and corresponding transfer functions enhances the value, and facilitates the use, of the theory presented in this book.

The volume was intended as a textbook for engineering schools in East Germany. This accounts for its translation from Russian into German as well as for the inclusion of such topics as Michailov's and Neimark's stability criteria and Solodonikoff's theory of determining time response from frequency response. The opportunity thus afforded to gain knowledge of Russian treatment of basic aspects of control theory should make Mejerov's book especially interesting to all teachers of feedback-control-system theory. However, the practicing control engineer will find much of value, too.

. . . on Control Engineering

REGELUNGSTECHNIK: KURZE EINFUHRUNG AM BEISPIEL DER DREHZAHLREGELUNG VON WASSERTURBINEN (*Control Engineering: Fundamentals with Application to the Speed Control of Hydraulic Turbines*). G. Hutarew. 176 pp. *Published by Springer-Verlag, Berlin, Germany,* 1955. 18 *D.M.*

This book is written in much the same style as two well-known earlier German works on speed control of turbines: namely, Tolle (1921) and Fabritz (1940), reviewed in CONTROL ENGINEERING, December 1954, page 50. The analysis is more up-to-date, however, in that system performance is analyzed through use of the modern tools of block diagrams, transfer functions, and frequency-response plots, rather than by differential equations alone, as in these older texts.

A feature of the present text is its wealth of specific systems. These are analyzed in detail to illustrate application of the general body of theory derived in the text. A typical example illustrates the system as a whole; it pictures the physical components that parallel individual units of the block diagram; derives the equations of performance; gives a frequency-response plot of the open-loop transfer function; determines the stability of the system by use of Hurwitz's, Leonhard's, or Nyquist's criterion; and lists the relative merits, shortcomings, and means of improving performance.

Thomas J. Higgins
Professor of Electrical Engineering
University of Wisconsin

WHAT'S AHEAD: MEETINGS

MAY

Symposium on Reliable Applications of Electron Tubes, RETMA Engineering Department, IRE Professional Group on Electronic Devices and JETEC, University of Pennsylvania, Philadelphia, Pa. May 22-23

Armed Forces Communications and Electronics Association, Boston Chapter, 10th National Convention, Statler Hotel, Boston, Mass. May 24-26

American Society for Testing Materials, Fourth Conference on Mass Spectrometry, Netherlands Plaza Hotel, Cincinnati, Ohio May 27

JUNE

American Society of Mechanical Engineers, Semi-Annual meeting, Statler Hotel, Cleveland, Ohio June 17-21

Stanford Research Institute and the University of California, Symposium on "High Temperature–a Tool for the Future" (methods, materials, and processes for high temperatures), University of California, Berkeley June 25-27

American Institute of Electrical Engineers, Summer and Pacific General Meetings, San Francisco June 25-29

AUGUST

The Association for Computing Machinery, 11th Annual Meeting, University of California, Los Angeles Association address: Box 3251, Olympic Station, Beverly Hills, Calif. Aug. 27-29

SEPTEMBER

American Society of Mechanical Engineers, fall meeting, Denver, Colo. Sept. 17-20

Instrument Society of America, 11th Annual Instrument-Automation Conference and Exhibit, N. Y. Coliseum, N. Y. Sept. 17-21

Institute of Traffic Engineers, 26th Annual Meeting, Mark Hopkins Hotel, San Francisco, Calif. Sept. 25-28

LOCKHEED in GEORGIA
MOVES AHEAD AGAIN!
Staff of 500 Seen For A-Plane Plant
W. R. Rhoads to Head Dawsonville Project, To Be Biggest of Its Type in Nation
Lockheed Aircraft Corp., wasting no time in the development of nuclear aircraft testing facilities at Dawsonville, announced Tuesday that W. R. Rhoads will head up the Dawsonville project.
Mr. Rhoads, who lives at 120 Osner Dr., NE, is chief staff engineer at Lockheed's Marietta plant now. He has been with Lockheed since 1941.
He will direct the work of the approximately 500 scientists, engineers and service personnel who will be employed at the Dawsonville site.
LOCKHEED AND the Air Force officially announced Monday night at a dinner at Gainesville that they intend to build a 10,000-acre, multi-million-dollar nuclear aircraft test site just southwest of Dawsonville (population, 350).
And, perhaps as significantly, Lockheed's top Georgia executive hinted that the actual manufacture of a nuclear-powered plane—perhaps the world's first—might take place at Lockheed's Marietta plant.
AND
there's more that can't be published—yet
The expected date
expected, but
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The world's largest integrated aircraft plant, at Marietta, Georgia, — where we build Lockheed C-130 Turbo-Prop Cargo planes and B-47 Jet Bombers—welcomes this new Lockheed program in Georgia.
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Taller & Cooper's Weigh-tronic scale can put its electronic finger on an overweight axle even if a vehicle is barreling along at 60 mph. Now in use under Indiana's East-West Toll Road, the scale sounds an alarm when a predetermined weight is exceeded, and records the passage of the axle, the time it passed, the entry station, etc.

TO NEW FAHREN-HEIGHTS

Temperatures of more than 400,000 deg F don't exactly dilly-dally around the laboratory (they last about a millionth of a second), but they remain long enough to get a reading on them. That's just what the Air Force has done, and according to the Air Research & Development Command there's no secret about the technique.

DRAWN TO SCALES

Two Richardson bagging scales pulled in the visitors at a recent industrial fair in Paris, France. The scales were manufactured by French and Italian firms under a Richardson Scale Co. franchise. The French firm, Les Grands Moulins Duquesne, built the first automatic feed mill in Europe.

INCISION, PRECISION, TELEVISION

From Germany comes a panel-operated surgical lamp whose oversize proportions permit installation of an X-ray tube, a TV camera, and a still-shot camera. The lamp's nineteen projectors can flood the patient with light or concentrate rays on any part of his anatomy. The manufacturer is Quarzlampen Gesellschaft.

AUTHOR JEUDON MOVES

Two French control engineering firms have merged into Groupement Francais pour le Developpement de l'Automatisation. One of the merged companies, Societe d'Electronique et d'Automatisme, is home base for CtE author A. Jeudon (see April '56 issue, p. 65). The other is Compagnie pour la Fabrication des Compteurs.

EDITORS WANTED

CONTROL ENGINEERING's expanding editorial content requires that we add two Assistant Editors to the Staff in the very near future. We are looking for men, preferably in the age group 25 to 35, with the following backgrounds:

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BS in ME, EE, Aero, or Physics, with a minimum of two years' experience in designing and applying control systems and some writing ability. This man will operate initially under the supervision of an Associate Editor, and will deal with manuscripts obtained in the field. Near future prospects: a senior technical editing post on the magazine.

ASSISTANT EDITOR

BS in any engineering curriculum or AB in Physics, with a minimum of five years' experience in the field plus a demonstrated technical reporting ability. This man will go out on field reporting assignments and will work with the Managing Editor on various departments of the magazine.

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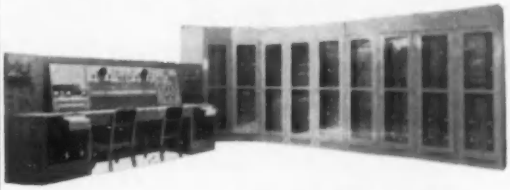

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WHAT'S NEW

(*Continued from p. 38*)

analytical and process control instruments) and the **Engineering & Optical Div.** (design and production of precision optics, and related research and development on a contract basis). General managers are: Instrument, Dr. Van Zandt Williams; E&O, Dr. Roderic M. Scott. Last March was P-E's greatest sales month, shipments running over $1 million.

Companies A-Building

▶ An environmental test laboratory (23,000 sq ft) for **General Precision Laboratory, Inc.,** in Pleasantville, N. Y. When completed late this year, the structure will handle wide ranges of altitude pressures, temperatures, acceleration forces, humidities, and vibration frequencies.

▶ A new settlement for **Varian Associates** in Palo Alto, Calif. New buildings in this "master plan" will more than treble the working space now confined to a laboratory and office buildings in Stanford Industrial Park, Palo Alto, and a microwave tube factory in San Carlos, increasing this space to 500,000 sq ft. One large building is earmarked for the **Instrument Div.,** another for the **Vacuum Tube Mfg. Div.,** still others for administrative offices.

▶ An engineering and sales office (4,500 sq ft) in Los Angeles for **The Liquidometer Corp.** of Long Island City, N. Y. The one-story plant will overhaul and repair the company's line of liquid gaging instruments.

▶ A new wing (27,000 sq ft) for the Boulder, Colo., laboratories of the **National Bureau of Standards.** The wing, to be staffed by 40 specialists, will house electronic equipment for calibrating military and industrial components.

▶ More space for **Minneapolis-Honeywell's Aeronautical Engineering Center** in West Los Angeles, Calif. The center, a section of the **Aeronautical Div.'s Aeronautical Engineering Dept.,** recently developed an automatic pilot system for supersonic jets. A tip from General Manager John Sigford and Supervisor of Administration William D. O'Brien: help wanted.

▶ Four plants ($25 million) for **Borg-Warner Corp.:** a $10-million chemical plant for the **Marbon Chemical Div.** in Washington, W. Va., an electronics plant and laboratory for the **Byron Jackson Div.** in Santa Ana, Calif., a research center in Des Plaines, Ill., and an automobile components

plant ($11 million) in Letchworth, England.

► A manufacturing plant (60,000 sq ft) for **Beckman Instruments, Inc.**, in Munich, Germany. The three-story, $300,000 plant, the first to be built in Munich by an American company, will provide larger quarters and a more relaxed business atmosphere (i.e., no import restrictions, currency problems) for **Beckman Instruments, G.m.b.H.**, the company's German incorporation. Indications are that Munich has become the center for nuclear energy studies in Germany, and Beckman, recognizing this, plans to set up its own research and engineering group in the new plant, scheduled for completion this October.

► Consolidation for **Automatic Electric Co.** (a 1.3-million-sq-ft headquarters plant) in Chicago. The one-story manufacturing facility, two-story office building, and research and development laboratories that will rise from the former Westward Ho golf course will bring together activities now carried on in fifteen buildings on Chicago's West Side. Two cafeterias seating 1,400 and 750, respectively, and a parking lot accommodating more than 3,000 cars are part of the Northlake project. Completion is set for 1957.

► Larger San Francisco facilities (a 120 per cent increase) for **General Controls Co.** The 4,400-sq-ft showroom-warehouse will include offices, test areas, and meeting rooms.

► A new factory (12,000 sq ft) in Ames, Ia., for **Bourns Laboratories.** The facility is an item in an expansion program centered in the company's home town of Riverside, Calif.

► A new location (three times as much room) for **Airmatic Valve, Inc.**, in Cleveland. An increase in engineering personnel is going forward under Henry Gardner, head of the engineering department.

► Two mergers: **Baird Associates, Inc.**, and **Atomic Instrument Co.**, to be implemented by an exchange of 2¼ Baird shares for every five shares of Atomic Instrument stock. The companies will operate as divisions of a new corporation, with Walter S. Baird as president and Leonard W. Cronkhite (Atomic Instrument) as vice-president for marketing. And **Sorensen, Ltd.**, of Zurich, Switzerland, European subsidiary of **Sorensen & Co., Inc.**, and **Applied Research & Development, Ltd.**, also of Zurich.

► And an acquisition: the potentiometer business of **General Components Co.** by **Minco Engineering & Mfg.** of Minneapolis, Minn. GCC is a division of **Washington Machine & Tool Works, Inc.**

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Now that Joe is on the team here at Farnsworth, he's asked me to write and give you the same story that got him interested in coming with us.

Actually, Bill, it wasn't a "story." Just a few honest-to-goodness reasons why he and Marge should make the move and let the family really <u>live</u> as well as let Joe grow professionally.

For instance, do you know what "sold" Marge? The fact that in living here you are only 10 minutes from everywhere—schools, churches, stores etc. and Joe goes home for lunch every day instead of week-ends. She also liked the idea of some 300 lakes within 70 miles. (Guess where they're planning to spend the summer!)

As for Joe, he's all hopped up about the work he's doing on such missiles as Bomarc, Talos, Terrier and others. Says the top-notch scientists and engineers he's working with are all big league and he's on the team.

That's about it, Bill. An engineer with your talents shouldn't be waiting around when he can get in on the ground floor here at Farnsworth in research, development or production engineering in missile guidance and control, radar, microwaves, test equipment, countermeasures, transistor applications etc.

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Sincerely, Jack

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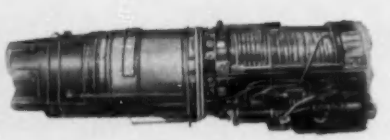

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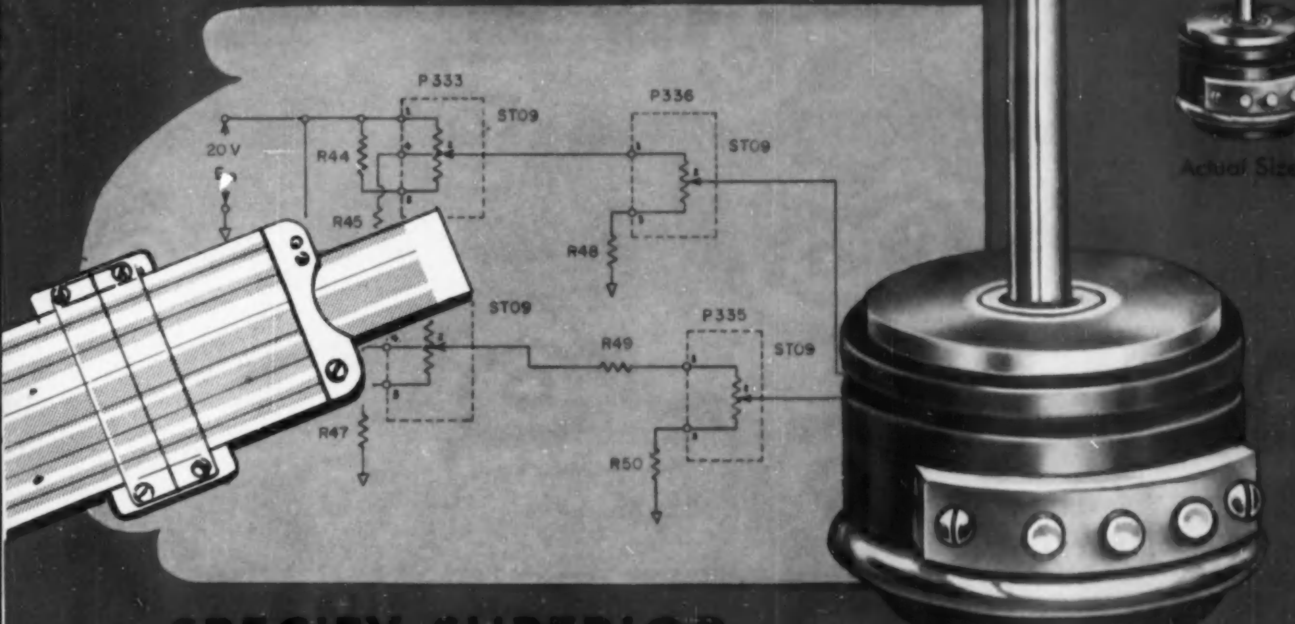

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